EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. IV. MAY, 1927. No. 44.

Editorial.

The Short-wave Echo Effect.

VIRTUE carried to excess may become a vice. This has happened with short-wave transmission, the principal virtue of which was the small attenuation with which the waves could travel to very great distances, even to the Antipodes, thus enabling schoolboys with a few watts to accomplish at times that which the wireless companies had failed to do with hundreds of kilowatts under the old dispensation. But, unfortunately, these short waves do not die out on arrival at the Antipodes but continue their journey around the globe with strength enough in some cases to cause serious interference with the waves which have taken the shorter path. This phenomenon was discussed by E. Quäck in the December number of the *Zeitschrift für Hochfrequenztechnik*, and was mentioned by T. L. Eckersley in a recent paper before the Wireless Section of the Institution of Electrical Engineers.

In October last the Radio Corporation of America began to transmit to Berlin from 2XT on 16.175 metres with an aerial input of 12 kilowatts. In full daylight a speed of 80 words per minute was reached, but the signals as recorded on the tape were often mutilated in a way that suggested that the waves which had travelled in the other direction around the globe were arriving a little after those which had taken the shorter path and interfering with the signals. At times the interference made working impossible. Fig. 1 is reproduced from a sample of tape given by Quäck. It shows how the letters *a b c* (·— —··· —·—·) are mutilated. To investigate the phenomenon more fully, the engineers of the Telefunken Company received the signals on an oscillograph and the American station sent simply five dots per second. Fig. 2 shows the result; the middle curve is produced by a 50 cycle alternator and gives the time scale; the

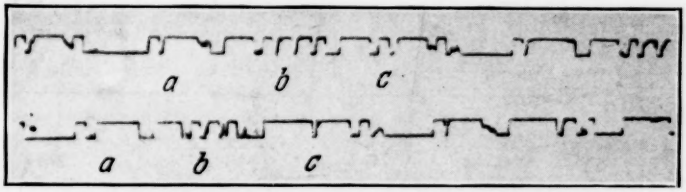


Fig. 1.

upper and lower curves show the same signal as received on two different aerials: the oscillograph has three loops. The main signal is marked *a* and the echo signal *a'*; one of the aerials was a dipol or Hertz aerial so inclined with reference to the polarisation of the waves that it showed no sign of the echo signal; on the other aerial the echo signal has about half the amplitude of the direct signal and arrives about 0.096 second later. At a speed of 299,800 kilometres per second this corresponds to a difference of path of 28,382 kilometres. To obtain greater accuracy the test was repeated, using an alternating current of 1,880 cycles per second to give the time scale. The result is shown in Fig. 3; this gave the time as 0.0957 second and the difference of path as 28,705 kilometres.

The difference between the signals received on the two aerials in this test is not always observed; sometimes both aerials receive the echo signal equally well.

A still more striking experiment consisted in transmitting from Nauen on a wavelength of 15 metres and a power of 8 kilowatts and receiving the signals at Geltow, both stations being near Berlin. The oscillograph of the received signal is shown in Fig. 4, *a* being the signal received directly over a distance of a few kilometres and *a'* that due to the waves which have encircled the globe. The time lag corresponds to a distance of 41,200 kilometres, which is more than the great-circle circumference of the earth, but is the length of path which the waves would have if they travelled at a height of 182 kilometres.

This echo phenomenon has only been observed with wavelengths between 15 and 22 metres but, as Herr Quäck points out, this range may be extended by the use of more sensitive receiving apparatus.

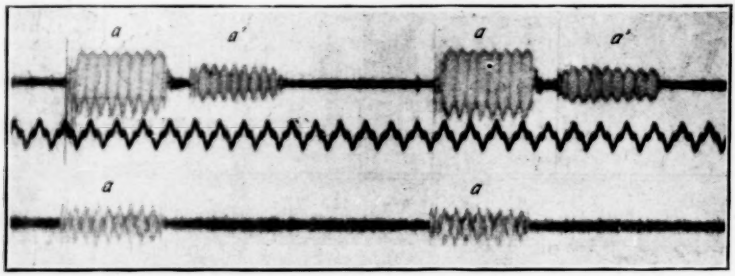


Fig. 2.

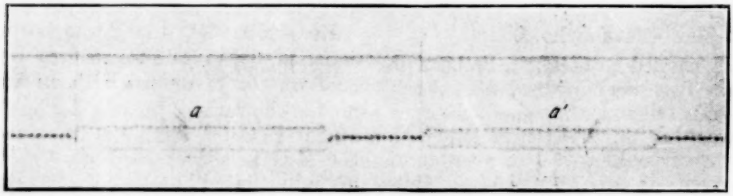


Fig. 3.

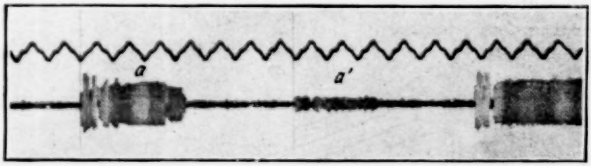


Fig. 4.

Phase and Group Velocities in an Ionised Medium.

By Prof. G. W. O. Howe, D.Sc.

IN the interesting experiments made in Berlin* to determine the time taken by a short-wave signal to encircle the globe, the length of path, and thus the height of the path above the earth, was deduced by multiplying the time interval by the velocity of light. To obtain an accurate value of the height, two things must be known to a very high degree of accuracy, viz., the time interval and the velocity of the wave, assuming, of course, that the ray follows a great circle at a fixed height. The need for great accuracy is due to the fact that the height is deduced from the difference between two very large distances, viz., the length of the path of the ray and the circumference of the earth. The results already obtained show that there is no insuperable difficulty in measuring the time interval to a high degree of accuracy, and, since the value obtained for the height of the ray is much greater than that hitherto considered probable, one is justified in wondering if the velocity of the wave may be appreciably less than that assumed. At first sight such an assumption appears to be quite contrary to the generally accepted theory that the waves are only able to encircle the globe because they travel in an ionised atmosphere in which their velocity is *greater* than that in free space. This contradiction is only apparent, however, as will be seen from the following considerations. When a train of waves, as shown in the figure, travels through an ionised medium, there are two different ways in which we can define the velocity. We can regard the group of waves as a whole, without considering the individual waves of which it is composed; if then the figure represents the positions of the group or train of waves at two successive moments of time, the distance travelled during the interval is D_g, and this distance divided by the time gives the group velocity. On the other hand, we may fix our attention upon any given crest, say that marked $\times$, and trace its progress. As the wave moves forward through the ionised medium, the vanguard *abc* is robbed of its energy in setting the electrons into oscillation, and this energy, less what is dissipated by electronic collisions, tends to maintain the waves as they die away. There is thus a continual eating away of the head and building up of the tail of the group of waves, with the result that our marked crest $\times$ gradually moves towards the head of the group. The distance D_p through which the marked crest has travelled during the interval divided by the time gives what is called the phase velocity. Now the phase velocity v_p is obviously greater than the group velocity v_g, and it can be shown that, whereas v_p is greater than the velocity c of light in a vacuum, v_g is smaller than c.

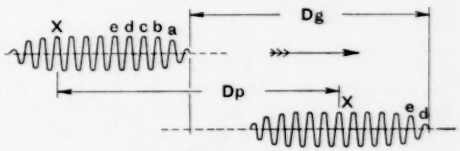


Fig. 1.

Now the curvature of the ray depends on the phase velocity v_p, and the short-wave ray is bent round and made to follow the curvature of the earth because this velocity is greater than c. The measurements made in Berlin determined the time taken for the group of waves to encircle the globe; and since this will depend on the time of arrival of the group of waves constituting the signal, irrespective of the individual waves, it will depend on v_g, which, as we have already said, is less than c.

It can be shown that

$$v_g = c\sqrt{(1-a)}$$

and

$$v_p = c/\sqrt{(1-a)}$$

where

$$a = \frac{N}{f^2} \cdot \frac{e^2 c^2}{\pi m}.$$

N = number of electrons in one cubic centimetre.

e = charge per electron = 1.591×10^{-20} electromagnetic units.

* E. Quäck, *Zeitschrift für Hochfrequenztechnick*, December, 1926, p. 177.

m = mass of electron = 0.9×10^{-27} grammes.

f = frequency = 15×10^6 for a 20-metre wave.

$$e^2 c^2/\pi m = 8.055 \times 10^7$$

and for $\lambda = 20$ metres.

$$a = N \times 3.57 \times 10^{-7}$$

Now for the group velocity v_g to differ by 1 per cent. from the velocity of light, it would be necessary for a to equal 0.02, whilst for v_g to differ by 5 per cent. a would have to be about 0.1. The above expression for a shows that

if $a = 0.02$; $N = 56{,}000$
if $a = 0.1$; $N = 280{,}000$

These are quite reasonable values of N. Appleton and Barnett deduced for certain conditions a minimum value of N of 100,000, and Appleton has recently (*Electrician*, 11th March) deduced a minimum value of 2.5×10^6. These are sufficient to show that the group velocity of the 20-metre wave may be several per cent. less than the velocity of light in a vacuum.

From the experimental results, Quäck calculated that the wave must have travelled at a height of 182 kms. If, however, we assume a velocity less than 299,800 kms. per second,, this height will be reduced. With a velocity 1 per cent. less than that assumed, the height would be reduced to 116.5 kms. and with a velocity 2 per cent. less the height would only be 51 kms.

It would appear, therefore, that the result of the experiment is not to determine the height at which the ray travels, but rather to determine from the assumed height the value of N the electron density in the medium through which the ray travels. Nothing very definite can be said on this point at present, because Herr Quäck expressly states that his results make no claim to great accuracy. Assuming the correctness of his figure of 182 kms. for the height of path based on a velocity of 299,800 kms. per second, we have the following results :—

If v_g =	0.99c	0.98c.
a =	0.02	0.04
N =	56,000	112,000
true height =	116.5 kms.	51 kms.

In a note in the *Wireless World* of 23rd March by a Berlin correspondent, it is stated that the height calculated from the German experiments is 350 kms. and not 182 kms. as given by Herr Quäck. If we adopt this figure we obtain the following results :—

If v_g =	0.98c.	0.97	0.96	0.95
a =	0.04	0.06	0.08	0.10
N =	112,000	168,000	224,000	280,000
true height =	216 kms	148 kms	81 kms	14 kms

It will be seen that N varies but little under these various assumptions ; an accurate determination of the time taken to encircle the globe would decide within narrow limits the electron density of the medium through which the ray travels.

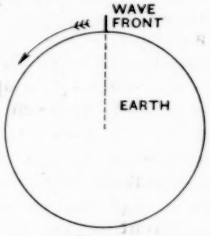


Fig. 2.

It is interesting to note that if the wave-front be assumed to travel around the earth, while the front itself remains radial as shown in the figure, so that the phase-velocity is proportional to the distance from the centre of the earth, then the group velocity must be inversely proportional to the distance to the centre, since $v_p \times v_g = c^2$. If now we assume that at the surface of the earth the velocity is the same as that in a vacuum, we can determine at what height the group velocity corresponds to the observed time interval. If we assume that the time interval gives a height of 182 kms. on Herr Quäck's calculation, it can be shown that the real height is about 90 kms., since at this height we are 1.0141 times further from the centre of the earth than we are on the surface. Hence $v_r = 1.0141\ c$ and $v_g = c/1.0141$; this reduction in the group velocity is just sufficient to reduce the calculated height from 182 to 90 kms. This would correspond to an electron density of about 80,000.

The Alignment Method in Linear Valve Characteristic Fields.

By W. A. Barclay, M.A.

BY the "linear field" of a valve characteristic, the writer intends that portion of the characteristic surface for which the individual characteristic curves are sensibly linear. It is within the linear field of the characteristic that it is desirable to confine the working point for the distortionless amplification of sinusoidal E.M.F.s. In what follows we shall confine ourselves entirely to a discussion of this linear field, and shall not be concerned with the curved portions of the characteristics and the problems to which they give rise.

It will be appropriate here to recall that the curves known as valve characteristics summarise in a convenient graphical form the statistical relations between various elements in the valve under usual working conditions. For the anode circuit of a valve the most important of these are: (1) The anode potential v_a, (2) the grid potential v_g, (3) the anode current i_a, and (4) the filament current i_f, upon which depends the filament temperature. For any given valve these four variables are inter-related, and the usual valve characteristic graphs show the relation between the first three only, the filament temperature being assumed to remain constant. We shall also avoid in the sequel all reference to the grid circuit of the valve, and neglect the reactions of any grid current upon the source of E.M.F.s. This assumption is quite justified for the negative values of v_g usually employed for voltage amplification.

With this proviso, and excluding the filament temperature from consideration, there are three possible graphical methods by which the relation between v_g, v_a and i_a may be shown, according to the three possible ways of selecting the co-ordinate axes. If OX and OY be taken to represent v_g and i_a respectively, the characteristic curves will represent values of v_a. This is the most usual type of valve characteristic whose uses are doubtless familiar to every reader. When OX and OY represent v_a and i_a, the individual curves represent values of v_g. This type of characteristic is used when it is desired to illustrate the effect of various kinds of load in the anode circuit, and has been dealt with recently in these pages. It may be mentioned that the slope of this characteristic gives a measure of R_0, the A.C. anode resistance of the valve at the working point. We have, when v_g is constant, $\partial v_a/\partial i_a = R_0$, so that the gradient of the curve is proportional to $1/R_0$. The third type, in which v_a and v_g are taken as axes while individual curves represent values of i_a, is only occasionally used.* In this type the slope of the "straight" portion gives an approximation to the amplification ratio μ_0 of the valve, *i.e.*, $\partial v_a/\partial v_g = \mu_0$.

It should be noted that each of the three graphical methods conveys the same essential information (which might equally well be set out in tabular numerical form). The differences between them lie only in the mode of presentation. In each, a portion of the graph is appropriated to the linear field, within which all the curves are approximately straight and sensibly parallel. It is in virtue of this fact that we may write the following equation, which holds only within the linear field:—

$$i_a = \frac{v_a + \mu_0 v_g - v_0}{R_0} \qquad .. \quad (1)$$

This equation, in which μ_0, v_0 and R_0 are constants, expresses the linear relationship between v_a, v_g and i_a. The linear field of each of the above three graphical types of characteristic may thus be represented by this equation when the axes of co-ordinates are appropriately chosen.

A brief word may be given to the three constants of this equation. R_0 is, of course, the anode A.C. resistance of the valve, or, as it has been termed, the differential resistance $\partial v_a/\partial i_a$. For the purpose of facilitating the exposition, this resistance is assumed constant

* An example of this kind of characteristic occurs in Professor Fortescue's paper on "Sources of Distortion in the Amplifier," reported in the *Wireless World* of 16th January, 1924.

throughout the linear field, while μ_0, the amplification factor of the valve, is likewise assumed to be constant. The actual voltage magnification obtained by inserting a load in the anode circuit is denoted by μ. When this load is a pure resistance R, μ is always less than μ_0. We have, in fact,

$$\mu = \mu_0 \cdot \frac{R}{R + R_0}$$

The constant v_0 of equation (1) is not so well known as the other two. It represents the back E.M.F. due to the electronic current within the valve, *i.e.*, it measures the diminution of plate voltage caused by this current. Like the others, v_0 also is constant throughout the linear field. It has been termed the "space charge effect." *

The true nature of equation (1) is often lost sight of. It is important to remember that it is essentially an experimental equation, the constants of which must be determined by experiment for each individual valve. Naturally, these constants should be the best available from the observational data: in other words, the equation of the linear field should be the linear equation which most nearly represents the data within the limits of the field. Obviously it can never quite succeed in doing so, because the individual measurements are each affected by possible errors of observation, while in addition we know that the characteristic curves themselves are never strictly linear, however closely they may approximate to this form over a wide field.

In undertaking to find the constants μ_0, v_0 and R_0 for the linear field of any valve, the problem before us is, if we tackle it graphically (as is usually done), that of drawing the straight lines which most nearly pass through certain given points on the graph. The precise position and slope of these lines is by no means easy to determine with confidence, and mathematical methods depending upon the Theory of Errors and Least Squares may be rejected as altogether too recondite for the needs of the problem. Within recent years, however, the advent of the Alignment Principle has provided the experimenter with yet another tool in the correlation of his observations, a tool at once easy of application and efficacious in its results. The particular method described below, which is one of several elaborated by the writer for the representation of valve linear characteristics, will, it is confidently believed, be found to possess many important advantages over the graphical procedure. These may be briefly enumerated.

In the first place, the problem of drawing the best straight line among several approximately collinear points is replaced by the undoubtedly easier task of finding the position of the point which will best represent the intersection of several approximately concurrent straight lines. (See Figs. 1a and 1b.) A second great advantage of the Alignment Diagram is that upon it *all* values of *each* variable may be represented, instead of only a limited number in the case of *one*,

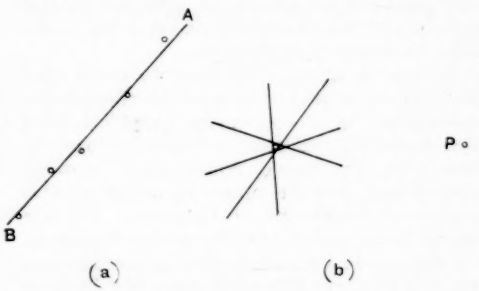


Fig. 1a. *These points may be represented by the line* A B.

Fig. 1b. *The intersection of these lines may be represented by a single point* P. (*The lines may be erased.*)

due to the inconvenience of multiplying unduly the number of lines upon the graph. A third feature is the exceedingly comprehensive nature of the diagram, which shows at sight the simultaneous variations of many more factors than can be made to appear conveniently upon the graph. Instead of having, as was shown above, one graph suitable for the estimation of μ_0, another for R_0, and so on, we have now one diagram upon which not only the variations of v_a, v_g and i_a can be read, but also those of the quantities v_0, R_0, R, μ_0 and μ. Moreover, no special construction need be drawn on the diagram to obtain these. The fourth and greatest advantage secured by the use of the new method is that the linear field characteristics of any number of valves may be drawn upon the same chart. The amplifying performance

* See "The Algebra of Ionic Valves," by Dr. Eccles in the *Electrician*, 13th February, 1920.

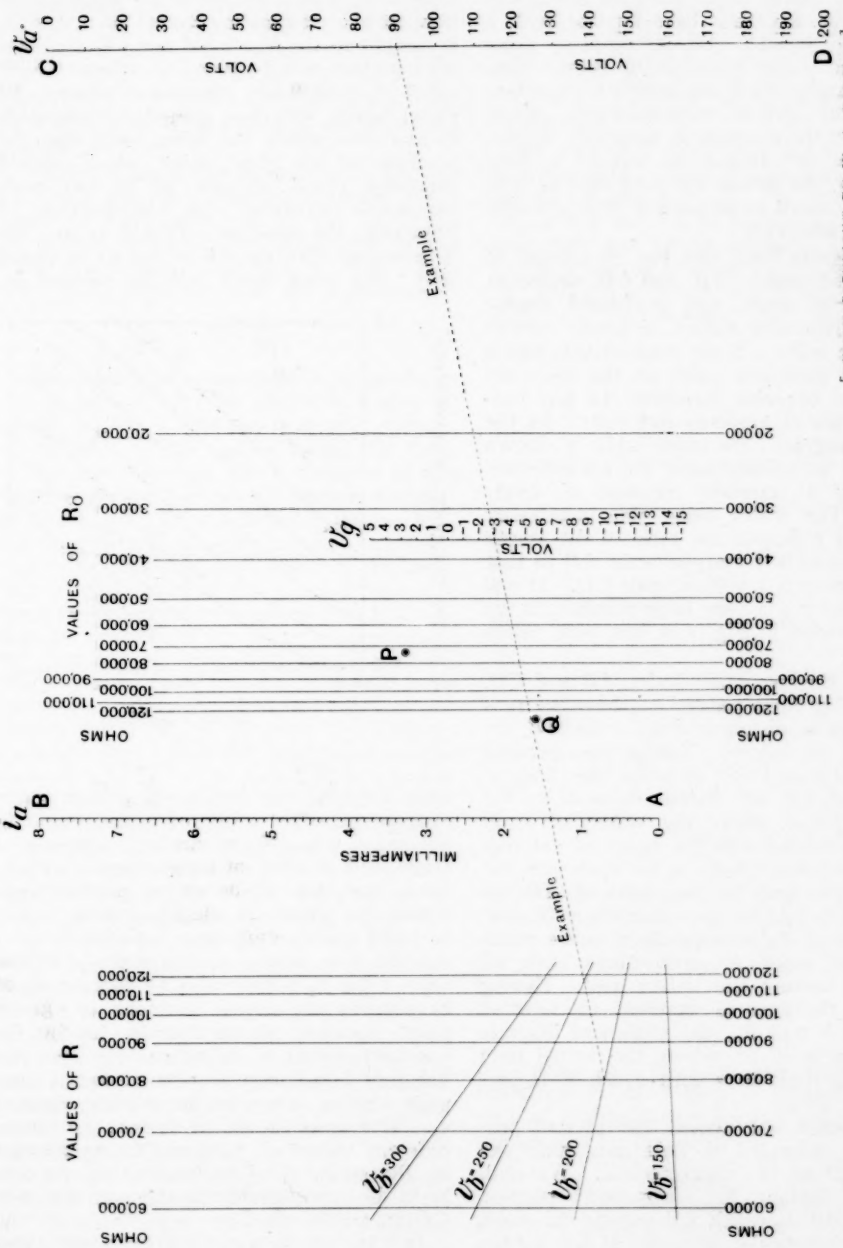


Fig. 2. *The example line shows that, for the particular valve illustrated, using an H.T. battery of 200 volts and an external resistance of 80,000 ohms, an anode current of 1.4 milliamperes flows when $V_g = -3$ volts; the actual anode voltage is 90, the voltage drop in the resistance being 110. The internal A.C. resistance is 35,000 ohms. For other values other scales of V_g may be drawn in.*

of different valves under different conditions of operation may thus be compared with a minimum of effort. This circumstance alone should, the writer ventures to think, commend the alignment characteristic to the attention of all serious experimenters. When constructed the diagram is simplicity to use, and while its preparation entails a little calculation, the labour involved will be seen to be very small in proportion to the results which are achieved.

The diagram itself (see Fig. 2) consists of two parallel scales, AB and CD, drawn at any distance apart, and graduated respectively to represent values of anode current and anode volts. These graduations, which may start from any point on the lines, are set out in opposite directions to any convenient scale of amperes and volts. In the present diagram, the scale AB is shown graduated in milliamperes for convenience, this being a standard measure of anode current. The scales being thus arbitrarily chosen, let r denote the ratio of the length which represents 1 amp on scale AB to that which represents 1 volt on scale CD. It will be seen that r is a very large number; in the case illustrated in Fig. 2 it has been taken as 20,000.

Besides the two main scales AB and CD, certain other lines parallel to these are now drawn, whose distances from scale AB are computed as follows: Taking the distance between AB and CD as unity, the lines to the left of AB are distant from it by the fraction $r/R—r$ where the values of R in ohms correspond with the range of external anode resistances likely to be used with the valves. The lines to the right of AB are distant from it by the fraction r/R_0+r, the values of R_0 corresponding to the range of internal anode A.C. resistances likely to be found among the valves used. Having drawn in the lines to represent the selected values of R and R_0, the alignment diagram is now prepared to receive the actual data concerning the valves with which it is proposed to deal.

As pointed out above, the present procedure is intended to deal only with the linear field of the characteristic. We shall therefore exclude for our present purpose all observations which fall outside this field. Using one particular valve, let us note all the pairs of values of i_a and v_a which are associated with a certain grid voltage v_g. If now such corresponding values of i_a and v_a be sought on the scales AB and CD, the lines joining them will be found to intersect each other in exceedingly contiguous points. So close, indeed, will these points of intersection lie (for data within the linear field) that the position of an ideal point which should represent them all can be plotted with reasonable accuracy. For the purpose of obtaining the position of this point, the intersecting lines should be drawn in pencil only; the point itself may be pricked in,

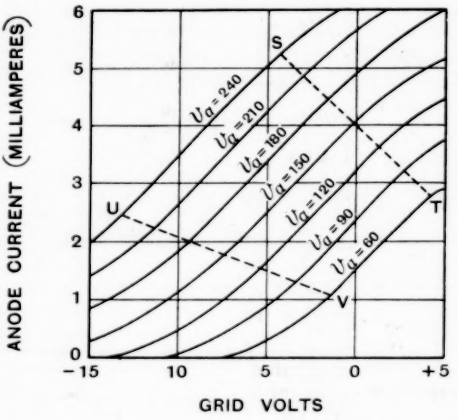


Fig. 3.

when the lines may be erased. Other points to represent other values of v_g are found in the same way within similar polygons of error, and if the work has been carefully done, and the observations plotted kept within the bounds of the linear field, it will be found that each of these v_g points lies on a straight line parallel to the scales AB and CD. (This fact may also be found helpful in plotting the actual positions of the v_g points, forming yet another line among the various polygons of intersection.) Upon the line thus found may now be entered a complete scale of values for the required range of v_g. This scale should be linear; *i.e.*, equidifferent values of v_g should be equidistant on the scale. The graduations should also lie in the opposite sense to those on the scale CD for anode volts.

In Fig. 2 such a v_g scale for a particular valve has been shown. For purposes of

comparison, the v_g–i_a characteristic curves of the same valve are reproduced in Fig. 3. In this graphical characteristic, the curves are drawn at intervals of 30 volts of anode potential. The limits of the linear field may conveniently be indicated by the dotted lines ST and UV.

The three scales now shown on the diagram of Fig. 2 provide a representation by alignment of the variations in the quantities v_a, v_g and i_a within the linear field of the valve in question. This is to say that within that field, they represent the equation,

$$i_a = \frac{v_a + \mu_0 v_g - v_0}{R_0}$$

We shall now show how the constants R_0, μ_0 and v_0 may be simply indicated by means of the alignment diagram. Firstly, the position of the v_g line among the mesh of R_0 lines affords a direct measure of the value of R_0 for the valve. Thus in the diagram of Fig. 2, the internal anode A.C. resistance is read as 35,000 ohms. If greater accuracy is required, the value of the ratio which the distance of the v_g scale from AB bears to the distance between AB and CD may be ascertained by direct measurement. By equating this ratio to the expression r/R_0+r, the value of R_0 may be more precisely ascertained. Next the valve amplification factor μ_0 is obtained by rotating a straight edge about any fixed point on the scale of i_a. If in its travel it is allowed to pass over a range of 1 volt on the v_g scale the corresponding number of volts passed over on the v_a scale determines the value of μ_0. In practice, it is well to allow the travelling line to pass over several volts on the v_g scale, dividing the corresponding range for v_a by this factor to obtain μ_0. In Fig. 2 it will be found that such a line, pivoted anywhere on AB, and traversing a range of 10 volts on the v_g scale, will pass through 110 volts on the v_a scale. Hence μ_0 for this valve is 11. Lastly, to arrive at the amount of the space charge effect v_0, a line is drawn through the zero values on the i_a and v_g scales. This line will meet the scale of anode volts in the value of v_0 for the valve.

Before going on to consider further applications of the alignment diagram, it may be well to supplement the above description with a mathematical proof of the properties so far considered. We shall suppose in what follows that on the scale AB a distance of α inches represents 1 ampere while on the scale CD a distance of β inches represents 1 volt. Then the fraction α/β is equal to r, the ratio between these scales already considered.

We shall first prove that the v_g points lie on a line parallel to AB, and distant from it by the fraction r/R_0+r. In Fig. 4, let P denote any value i_a of anode current on the scale AB, and let Q represent the corresponding value v_a of anode voltage on the scale CD which is obtained with a certain definite value of grid voltage, v_g. Keeping the

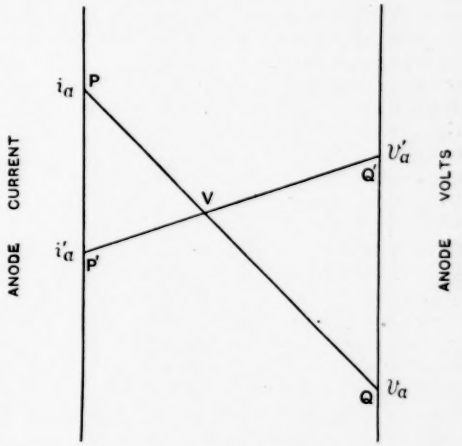


Fig. 4.

value of v_g constant, let P' denote a different value of anode current i_a', and let Q' represent the corresponding value of anode volts, v_a'. Let PQ and $P'Q'$ meet in V. Then, we have,

$$\frac{PP'}{QQ'} = \frac{\alpha(i_a' - i_a)}{\beta(v_a - v_a')}$$

But, when v_g is constant, the internal A.C. resistance of the valve is defined by the ratio of a change in v_a to the corresponding change in i_a. Hence,

$$\frac{PP'}{QQ'} = \frac{r}{R_0}$$

But, by geometry, the ratio PP'/QQ' is equal to the ratio of the distances of V from the lines PP' and QQ'. Therefore, the ratio of the

distance of V from PP' to the total distance between the scales is,

$$\frac{PP'}{QQ'+PP'} = \frac{r}{R_0+r}$$

The position of the point V is thus situated at a distance from AB depending solely on R_0, and is invariant with regard to the values of v_g. For all such values of v_g, therefore, the points V will lie on a straight line at the above distance from AB.

Next, we shall show that the v_g points on this line form a linear scale. In Fig. 5, let A represent the zero point on the scale of anode current, and let B represent the current value i_a. Let C on the scale of anode volts represent v_0, the space charge voltage, and D represent the actual anode voltage v_a. Let the line FKH be drawn dividing the distance between AB and CD in the ratio r/R_0. Then its distance from AB is to the distance between AB and CD as r/R_0+r, and the v_g points will lie along it, as shown above. Let AC meet FKH in H, and BD meet it in K. Also draw BE parallel to AC to meet HK in F and DC in E. Then,

$$AB = \alpha i_a$$
$$CD = \beta (v_a - v_0)$$

$$\frac{FK}{ED} = \frac{FH-HK}{EC+CD} = \frac{AB-HK}{AB+CD} = \frac{\alpha i_a - HK}{\alpha i_a + \beta(v_a - v_0)}$$

But $\frac{FK}{ED} = \frac{r}{R_0+r}$ by construction.

$$\therefore \quad HK = \alpha i_a - \frac{r}{R_0+r}\left\{\alpha i_a + \beta(v_a - v_0)\right\}$$

$$= \frac{\alpha}{R_0+r}\left\{i_a R_0 - (v_a - v_0)\right\}$$

But from equation (1)

$$i_a R_0 - (v_a - v_0) = \mu_0 v_g$$

Hence,

$$HK = \frac{\alpha \mu_0 v_g}{R_0+r} \quad .. \quad .. \quad (2)$$

i.e., the distance HK is proportional to v_g. But in equation (2) when $v_g=0$, $HK=0$, *i.e.*, K coincides with the fixed point H. Thus the point H represents $v_g=0$, and other values of v_g are represented by points whose distances from H are proportional to their amounts. Moreover, the scale to which these values appear on the diagram is 1 volt $= \alpha\mu_0/R_0+r$ ins., from equation (2). To prove the construction for μ_0, we may note that a movable line pivoted at any point on AB will traverse R_0+r/r ins. on CD for 1 in. traversed on HK. If, therefore, it traverse $\alpha\mu_0/R_0+r$ ins. on HK, it will traverse $\alpha\mu_0/r=\beta\mu_0$ ins. on CD., *i.e.*, for 1 volt on HK it passes through μ_0 volts on CD.

We may now proceed to show how the alignment diagram of Fig. 2 can be made to take account of the effect of an external resistance load, when this is introduced into the plate circuit.

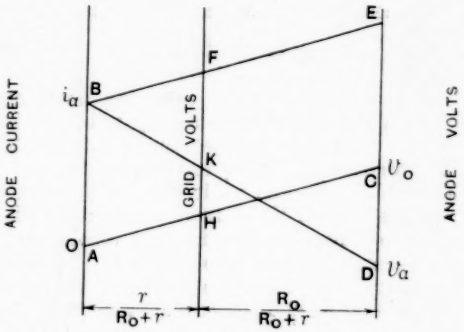


Fig. 5.

Taking on the scale of anode volts the point representing v_b, the value of the H.T. battery voltage, we join it to the zero of the i_a scale and produce till it meets the external resistance line corresponding to the required value R. This line need not actually be drawn, but the resulting point should be marked. Using this point as a pivot, it will now be found that any straight line drawn through it will meet the scales of i_a, v_g and v_a in points whose graduations correspond to the working conditions of the valve with load R within the linear field. For example, if a definite anode current be required, its value on the i_a scale is joined to the pivot R point. The necessary values of grid and anode voltage to produce this current are then read off in alignment on their appropriate scales, the voltage drop in the resistance being measured by the difference of v_b and v_a on the scale of anode volts. It is evident that the effect of varying the external resistance may be traced with ease, the various pivotal points for any given H.T. battery voltage being found on the various R lines as above explained. In passing, it is worth

noticing that these pivotal R points are in no way dependent upon the particular valve concerned, but merely upon the values of external resistance and battery voltage in use. It is thus possible to represent different values of v_b by a pencil of lines drawn through the zero point of the i_a scale to meet the mesh of external resistance lines. Upon the resulting network, the positions of the pivotal points for resistance load working can be sought with extreme facility. In Fig. 2, a pencil of four lines has been drawn to represent values of v_b at intervals of 50 volts. Such a network remains the same for all valves, an important feature when it is desired to compare the performance of different valves under similar conditions of H.T. potential and loading.

In the diagram of Fig. 2, the example line is shown passing through the values v_b=200, R=80,000. For the valve in question, if these values are used, an anode current of 1.4mA is seen to be obtained with a grid voltage of -3, while the same line further indicates that under these conditions the actual potential of the anode is 90 volts.

A proof of the alignment properties of the diagram for external resistances may now be given. In Fig. 6, let A represent the zero point on the scale of anode current, and let B represent the current value i_a. Let D

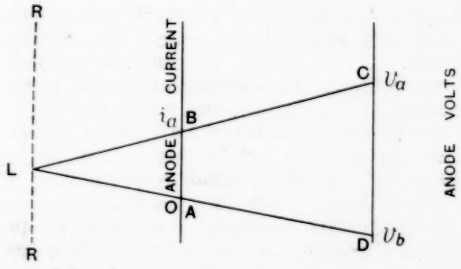


Fig. 6.

on the scale of anode volts represent v_b, the H.T. battery voltage, and let the line DA produced meet the external resistance line of the value R in the pivotal point L. Join LB, and produce it to meet the scale of anode volts in C. Then we must show that the point C represents the value v_a of anode potential. Now since, by construction, the distance of L from AB is to the distance between AB and CD as $r : R - r$, the distance of L from AB will be to its distance from CD as $r : R$.

Therefore, $AB/CD = r/R$

But $AB = \alpha i_a$ ins.

$\therefore$ $CD = \alpha i_a \cdot R/r$ ins.

$= \beta R i_a$ ins.

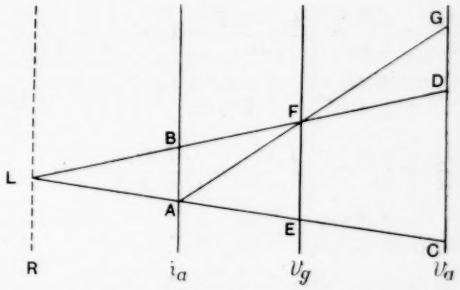


Fig. 7.

Since, however, in the external anode circuit, the voltage drop across the resistance is equal to the product of the current and the resistance (Ohm's Law), we have

$$Ri_a = v_b - v_a$$

so that

$$CD = \beta (v_b - v_a) \text{ ins.}$$

Thus the distance CD measures the difference $v_b - v_a$ on the scale of anode volts. Now, the point C must always lie *above* D (because B lies above A), and thus its value must always be *less* than v_b. Hence the point C represents v_a.

We now pass on to note the effect which the presence of an external resistance load has upon the voltage magnification obtained. The moving line used above to find the value of μ_0 was pivoted on any point on the scale of i_a. Using a resistance R, however, the line is pivoted about any point on the R line, and the intercept on the v_a scale for a change of 1 volt on the v_g scale read as before. The value of μ so obtained is obviously smaller than that of μ_0. To prove that it is actually $R/R_0 + R$ of μ_0, we may reason as follows:—

In Fig. 7 let EF represent any interval of 1 volt on the v_g scale, and take L, any point on the external resistance line, R. Join LE and LF, and let them meet the i_a scale in A and B, and the v_a scale in C and D respectively. Join AF, and produce it to meet the

v_a scale in G. Then it has been shown above that the distance CG represents μ_0 volts. We have now to show that CD represents μ volts.

We have, by the geometry of similar triangles,

$$\frac{GC}{FE} = \frac{AC}{AE} = \frac{R_0 + r}{r} \quad \ldots \quad \ldots \quad (\xi)$$

$$\frac{FE}{BA} = \frac{LE}{LA} = \frac{LA + AE}{LA} = 1 + \frac{AE}{LA} =$$

$$1 + \frac{AE/AC}{LA/AC} = 1 + \frac{r/R_0 + r}{r/R - r} = \frac{R_0 + R}{R_0 + r} \quad \ldots \quad (\eta)$$

$$\frac{BA}{DC} = \frac{LA}{LC} = \frac{LA}{LA + AC} = \frac{LA/AC}{(LA/AC) + 1} =$$

$$\frac{r/R - r}{(r/R - r) + 1} = \frac{r}{R} \quad \ldots \quad \ldots \quad (\zeta)$$

Multiplying together the right and left hand sides of equations (ξ), (η) and (ζ), we have

$$\frac{GC}{FE} \cdot \frac{FE}{BA} \cdot \frac{BA}{DC} = \frac{GC}{DC} =$$

$$\frac{R_0 + r}{r} \cdot \frac{R_0 + R}{R_0 + r} \cdot \frac{r}{R} = \frac{R_0 + R}{R}$$

i.e.,

$$DC = GC \times \frac{R}{R_0 + R}$$

Thus, DC represents μ volts.

The voltage magnification obtained with an external resistance is, of course, independent of the H.T. battery voltage used. For this reason, any point on the R line may be used as pivot when finding the value of μ. Using an external resistance of 80,000 ohms with the valve of our example, the effective valve magnification is easily seen from Fig. 2 to be 7.6, the percentage modification being thus 69 per cent.

The discussion has so far been limited to the case of one particular valve, and it has been shown how its various constants R_0, μ_0 and v_0 may be readily ascertained, and how its performance within the linear field is modified by the inclusion of an external anode resistance. It should be remembered that the fundamentals of the diagram are the i_a and v_a scales and the R_0 and R lines. The scale of v_g is peculiar to the individual valve; to other valves different scales of v_g will correspond, and may also be shown upon the diagram as vertical lines situated at appropriate positions for R_0. These other scales of v_g will all be linear, though they are quite distinct, their graduations bearing no relation to each other. On the facility with which the performance of different valves may be thus compared under various working conditions, the writer would base his chief claim for the use of the method in amplification work.

Throughout this article, care has been taken to emphasise the fact that the results obtained from the alignment diagram are only true within the linear field of the valve in use. It is natural to inquire if any limitations are imposed on the diagram by reason of this condition. To answer this question fully would take us too deeply into the theory of alignment for our present purpose, which is primarily that of exposition. Without attempting anything in the nature of reasoned proof, however, the writer may answer it by alluding briefly to the underlying principles of the alignment process. This is virtually an application of the "Principle of Duality," with which those who are acquainted with Modern Geometry will be familiar. Roughly speaking, this principle enunciates that to all theorems concerning points and straight lines, there correspond reciprocal theorems in which these entities have been interchanged, so that where before we had a theorem concerning a set of straight lines and points of intersection, we now have a corresponding theorem dealing with a set of points and the straight lines joining them. If the points in the first theorem were collinear, the corresponding lines in the second are concurrent and *vice versa*.

In its simplest form, the alignment method may be said to apply this "Principle of Duality" to the Cartesian representation of straight lines, which thus become points on the alignment diagram. For example, the straight portions of the characteristic curves of Fig, 3 become points on the v_a scale of Fig. 2. Again, the coordinate axes of the graph, representing zero values of v_g and i_a are replaced by the zero points on these scales in Fig. 2. Further, any point on the coordinate surface can be identified with a straight line on the alignment diagram which passes through those points on the scales corresponding to the coordinate values of the point. Now, it was found convenient to delimit the linear field of the characteristic curves in Fig. 3 by the lines ST and UV.

To these two lines, therefore, should correspond two definite points on the alignment diagram, and these are indicated on Fig. 2 by P and Q respectively. If the positions of these two points are known, we may apply the Principle of Duality to the delimitation of the linear field by "translating" the definition of the Cartesian field to suit the reciprocal diagram. For amplification, it is known that all working points on the graphical characteristic lie between the lines ST and UV. This statement is replaced for the alignment diagram by the equivalent assertion that *all working lines must lie between the points P and Q*. Here, then, is the required condition which every movable or index line applied to the diagram must fulfil, in order that it may represent a relation falling within the linear field of the valve.

It remains to indicate how the positions of P and Q are to be found. In Fig. 3, let S, T, U, V represent the limits of the linear field for ordinary amplification work. Let us suppose that the coordinates of these four points have respectively the values (v_{g1}, i_{a1}), (v_{g2}, i_{a2}), (v_{g3}, i_{a3}), (v_{g4}, i_{a4}). On the alignment diagram of Fig. 8, draw a line s joining the points v_{g1} and i_{a1} on their respective scales, and also a line t joining v_{g2} and i_{a2}. The intersection of these lines s and t gives the point P which represents on Fig. 8 the straight line ST of Fig. 3. Again on Fig. 8 draw a line u through the values v_{g3} and i_{a3}, and also v through v_{g4} and i_{a4}. Then the intersection Q of u and v represents the line UV of Fig. 3. The proof is complicated, and may be left to those readers who are conversant with projective geometry.

It may not be superfluous to devote a few words in conclusion to the practical working of the diagram. For the elucidation of the principles on which it is founded, it was assumed above that the quantities R_0, μ_0 and v_0 are true constants. This, in fact, is not strictly the case. Within the linear field itself these quantities, and especially R_0, are subject to variation. The effect of this upon the alignment diagram is that instead of the grid volts scale being a vertical line, it is in general slightly curved. This, of course, indicates very conveniently the variation of R_0 with grid voltage, a variation quite well established within the linear field. Strictly speaking, of course, R_0 is not a definite function of grid voltage alone, being subject also to slight variation with anode voltage. Within the linear field, however, this latter variation is negligible. The crux of the matter lies in the precise delimitation of the linear field. The extent of the region within which the curves on the Cartesian diagram may be regarded as "straight" is entirely arbitrary, and the limits assigned may vary for different purposes. These limits once fixed, however, it is possible to obtain on the alignment diagram the positions of optimum points to represent values of

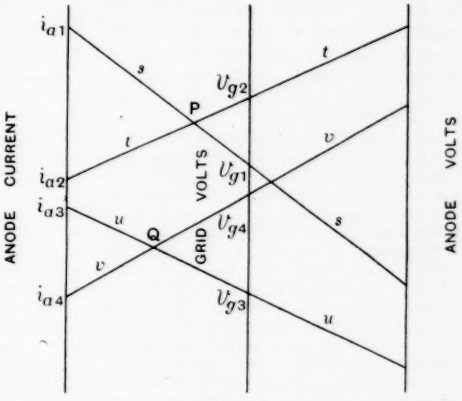


Fig. 8.

grid voltage in the manner described, the curve through which will support the v_g scale. Beyond these limits, of course, the method is not available.

The unique possibilities afforded by the diagram of indicating variation in anode A.C. resistance will not escape those experimenters who wish to follow approximately the effect of this important factor in amplifying work. There is, at present, a regrettable tendency on the part of manufacturers to quote a fixed value of R_0 for their valves, and it is thought that the ease with which the variations in this quantity may be traced will be found not the least commendable property of the alignment diagram.

It may be remarked that the foregoing is by no means an exhaustive account of the uses to which the alignment diagram may be put. In particular, nothing has been said regarding its many "inverse" functions.

For example, we have seen that for the particular valve illustrated in Fig. 2, to obtain 1.4mA with -3 volts on the grid, an H.T. supply of 200 volts together with an external resistance of 80,000 ohms are used. If the H.T. supply available is 250 volts, the value of the resistance necessary is read at the intersection of the same index line with the line $v_b=250$, and is seen to be 115,000 ohms. In each case the actual anode potential is 90 volts. The facilities offered by the diagram in the checking of experimental results need not be enlarged upon, and many other such inverse uses will present themselves to the reader who may be disposed to construct such a chart for his own valves. Enough has been said here in indication of a linear field characteristic which promises to be as useful practically as it is interesting theoretically.

Book Review.

ELECTRICAL CONDENSERS. By Philip R. Coursey. Pp. 637+xxiv. Price 37s. 6d. net. (Sir Isaac Pitman and Sons.)

In his preface to this book Mr. Coursey tells us that its purpose is to dispel the idea that condensers are merely fragile pieces of apparatus to be found in physical laboratories, and to show that they are important components of many large electrical installations, and that their industrial importance is very great and rapidly growing. There is no doubt that the book will achieve this object. A mere glance at a few of its five hundred illustrations will convince the reader, and he cannot fail to be impressed by the fact that here is a large book of over six hundred pages dealing almost exclusively with condensers.

For the most part, the book is encyclopædic in character. The construction of a large number of condensers of all types is described in some detail. These include small fixed and variable condensers for radio receiving circuits, large condensers used in transmitting circuits, condensers for the protection of high voltage transmission lines, and those for the improvement of the power factors of A.C. circuits; condensers with dielectrics of air, glass, paper, mica, oil, cellon, and, in short, condensers of almost every type that has ever existed. Even the synchronous condenser is included. Wireless enthusiasts will probably be interested in the chapter dealing with the scores of variable air condensers of different types. There are many good illustrations, not only of condensers, but also of the machinery used for making them, installations in which they are used on a large scale, and so on.

The purely scientific side of the subject has naturally received some attention, and in this connection the book is remarkable for the bibliography of some two thousand references which occupies its last hundred pages. The research worker will find this very valuable, although it seems somewhat out of keeping with the rest of the book. The fact is that it requires an expert to sort out the wheat and chaff in such an enormous list of references, whereas the book itself is evidently not primarily written for the expert. In many cases the scientific treatment is very superficial. For example, in dealing with the Weston microfaradmeter, we are told that "it makes use of a moving coil movement with pointer moving over a scale graduated in microfarads." We are then given a photograph of the instrument, and another of a number of girls using it in a test room, and the subject is dismissed. Again, in connection with the tuning of vibration galvanometers, the only information given is that it is done "by the rotation of the knob at the right hand side of the instrument" (illustrated). These are extreme cases, but there is rather a tendency when dealing with matters of scientific interest to put off the reader with a list of half-a-dozen references, when what he really wants is a short explanation. One would have preferred to see the subject of "earth capacities" and the screening of condensers treated in rather greater detail, and also the definition of capacity itself. Without a thorough understanding of these points it is impossible to apply in practice the formulæ for the capacities of spheres, etc., given in Chapter VI.

It is also a little disappointing that Mr. Coursey has not given us more of the benefit of his experience in a rather more critical treatment. He has usually been content to describe without comment. The secrets of good construction are certainly not revealed to us. We are even told that in standard mica condensers "mica and copper foil electrodes are commonly used with *shellac*, or a similar adhesive, to maintain the condenser in a rigid condition." Did Mr. Coursey write this with his tongue in his cheek?

The book contains valuable lists of the dielectric constants, dielectric strengths, resistivities and power factors of a large number of dielectrics. Some of the curves published by Curtis giving the properties of typical mica and paraffined paper condensers would have formed a valuable addition to this.

While the book does not satisfy all our needs, we must not lose sight of the fact that it is a mine of information on all matters relating to condensers, that it is well up to date, and so well provided with references that it will put us into touch with practically all there is to be known on the subject. For this we are grateful.

L. HARTSHORN.

Battery Eliminators

Or, Appliances for the Operation of Radio Receiving Circuits by Energy Derived from Electric Supply Mains.

Paper read by Messrs. P. R. COURSEY, B.Sc., M.I.E.E., and H. ANDREWES, B.Sc., before the Wireless Section, I.E.E., on 6th April, 1927.

ABSTRACT.

1. Introduction.*

THE modern radio receiver using thermionic valves requires to be energised from three distinct electrical sources, *i.e.*, (*a*) High tension, (*b*) Low tension, and (*c*) Grid bias. For all three a sensibly steady D.C. supply is necessary, the differences between them lying mainly in the voltage and current that they must deliver. The frequent replenishing and recharging of batteries has created a demand for apparatus which will replace them and provide equivalent voltages and currents derived from the public electric supply mains.

2. Scope of the Paper.

The purpose of the paper is to discuss the essential requirements of this class of apparatus, to consider the main features of its design and application, and to show the type of results that are obtainable in its use and in what direction further advances are required. A great deal of radio apparatus has in the past suffered from a lack of anything in the nature of real "engineering" design. The more extended use of appliances to supply these voltages may thus in time reflect on the design of the receiver itself from the point of view of insulation and general quality of construction. To some extent also it may ultimately affect the electrical design itself on account of the higher voltages made available for general use, without undue operating or maintenance expense.

3. Radio Supply Appliances.

The name of "Radio Supply Appliances" is suggested (in lieu of the more usual term "battery eliminators") as being of broader application. It is pointed out that a complication arises due to the voltages having a common connection at the valve filaments and also in the supply mains. Fig. 1 is given as illustrating a theoretical arrangement rather than a possible and actual one.

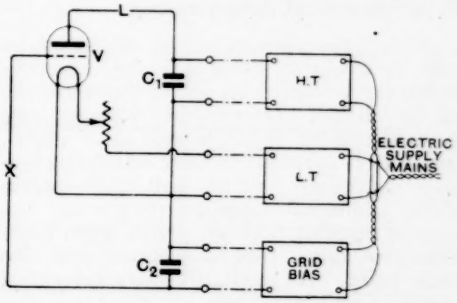


Fig. 1.

4. General Principles.

These are discussed only very briefly. It is pointed out that the precise arrangements depend in the first place on whether the supply is D.C. or A.C. In the latter case, some form of rectification must be provided, and that even the best D.C. supply circuit requires smoothing before application to the receiver.

5. H.T. Supply Appliances.

The first essential element of the H.T. appliance is a filter to perform the smoothing combined with a potentiometer or equivalent device for subdividing the applied voltage into one or more parts. For A.C. supply circuits rectification must also be added. Fig. 2 is given as showing the essential elements of a H.T. supply appliance for D.C. mains. The combination of C_1 L_1 and C_2 acts as a filter to suppress currents of higher

* The authors' original section numbers and figure numbers are adhered to throughout this abstract.

frequencies and to allow the lower frequency and zero frequency (direct current) to pass, the general form of the filler being of the "low pass" type. A further inductance and condenser may be introduced to improve the filtering efficiency.

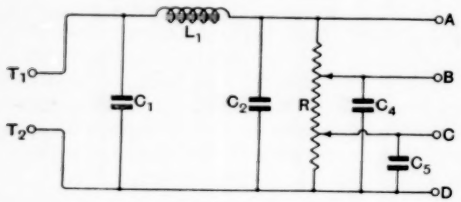


Fig. 2.

6. Adjustment of Output Voltage.

With a 200-240-volt supply, about 200 v. will be available across AD, the difference being the voltage-drop due to the resistance of the chokes. Intermediate voltages may be obtained by tappings such as B and C, while it is desirable to have additional by-pass condensers—of at least 1μF—across these additional tappings to prevent excessive coupling between valves when more than one valve stage is operated from the same point. An alternative arrangement of voltage taps is shown in Fig. 4. This

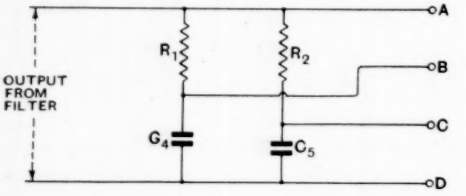


Fig. 4.

arrangement has the advantage of somewhat reducing the coupling between valves, since the total H.T. current is divided through different resistances. There is, however, somewhat greater voltage variation of the points B and C with varying load.

7. H.T. Filter.

The mathematical theory of filter circuits is not dealt with, the authors giving only a few general remarks. It is pointed out that, with a rectified A.C. supply, the input condenser is involved in the storage of the rectified impulses during a part, at least, of each cycle. It should therefore be of reasonably large capacity. With D.C. supply the ripple is not much (if at all) affected by this condenser. In some cases advantage has been taken of the fact in the manufacture of D.C. apparatus, by omitting the first condenser, but, in other cases, probably for the sake of simplicity or uniformity in manufacture, the same arrangement of filter condensers is used for both D.C. and A.C.

8. Design of H.T. Filter.

There are, in general, three electrical factors affecting the design of the filter. The commercial design is, to a greater or less extent, a compromise between considerations of electrical efficiency and cost. These factors are :—

1. The internal resistance of the chokes as affecting the "regulation" of the apparatus on load.
2. The resonance frequency of the filter, affecting its efficiency in removing "hum."
3. The output impedance at audio frequencies, controlled mainly by the output condenser capacity, and affecting the load which may be drawn from the filter without producing oscillation in the receiver.

The single filter circuit, of Fig. 2, may be regarded as a resonant circuit of L_1 and C_2 in series, and it is stated that the resonance curve of this filter was found to be unaffected by the capacity of the input condenser C_1, when subjected to applied alternating voltages at various frequencies. The load is effectively a resistance across C_2, damping this resonant circuit. The behaviour of various filtering arrangements are shown by plotting against frequency the ratio of the voltage V_0 across C_2 and the input voltage V_i, across C_1 of Fig. 2. A typical curve is shown in Fig. 6.

Figs. 7, 8, 9 and 10 show the effect of the different electrical dimensions given.

A group of characteristics for a double filter is shown in Fig. 11. Some of these curves show a subsidiary bump, which

might have a serious effect if it occurred near 50 or 100 cycles. The possibility of this emphasises the need for plotting the characteristics of any filter that is proposed for use in an H.T. supply appliance.

with a single detector appears to be much the same as when one or two L.F. stages are added. It appears to the authors that quite satisfactory results may be expected if the ripple voltage is of the order of 0.1 volt in

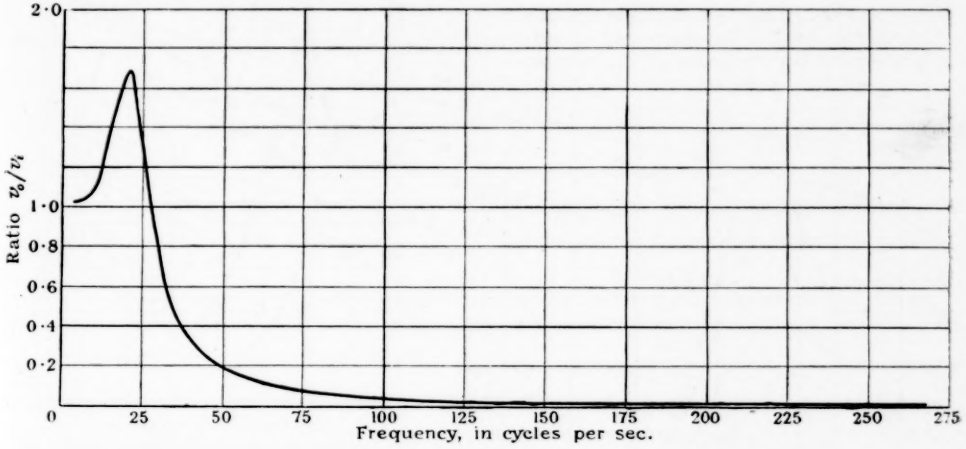


Fig. 6.

9. Permissible Ripple Voltages.

It is stated that experiments have shown the greatest source of disturbance to be the detector valve. With a given ripple voltage in the H.T. supply, the intensity of the hum

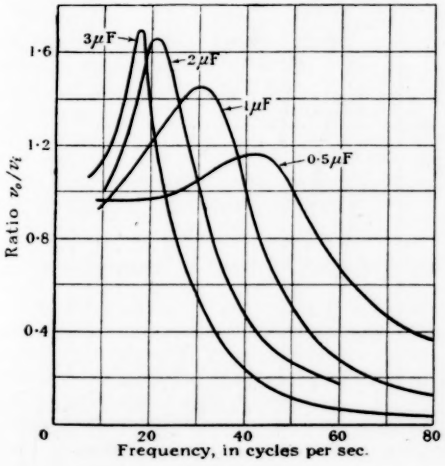


Fig. 7.

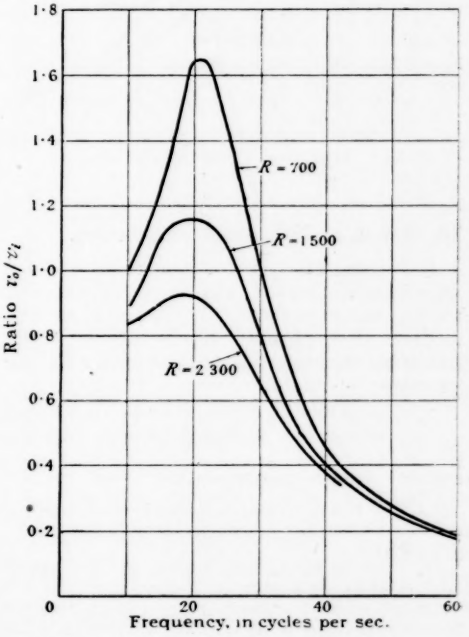


Fig. 8.

the H.T. circuit. Even with comparatively weak signals 0.2 volt of ripple is not particularly noticeable except during silent periods. With loud signals 0.25 to 0.4 volt does not particularly mar reception, although the hum becomes quite noticeable during silent periods. One volt of ripple appears to the authors to be excessive and could be improved by better design of the appliance.

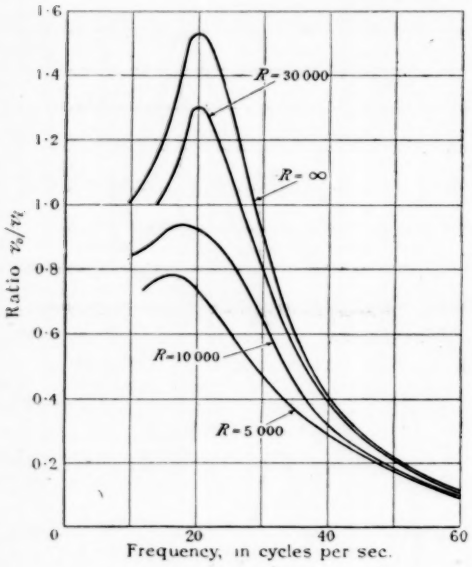


Fig. 9.

10. Rating of H.T. Supply Appliances.

It is suggested that the time is ripe for the formulation of a definite scheme of rating these devices. It appears to the authors that possibly two or three of the following characteristics might suffice for the purpose :—

1. The percentage regulation of the output voltage at a stated output current, *e.g.*, 1mA.

   $$\text{This quantity} = \frac{100 \times \text{voltage-drop at 1mA output.}}{\text{Initial voltage at zero output.}}$$

2. The internal impedance of the appliance expressed in ohms.

   $$\text{This quantity} = \frac{1{,}000 \times \text{voltage-drop.}}{\text{Load current, in mA.}}$$

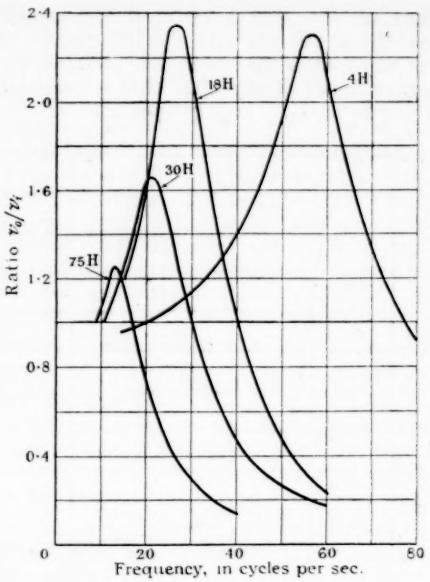


Fig. 10.

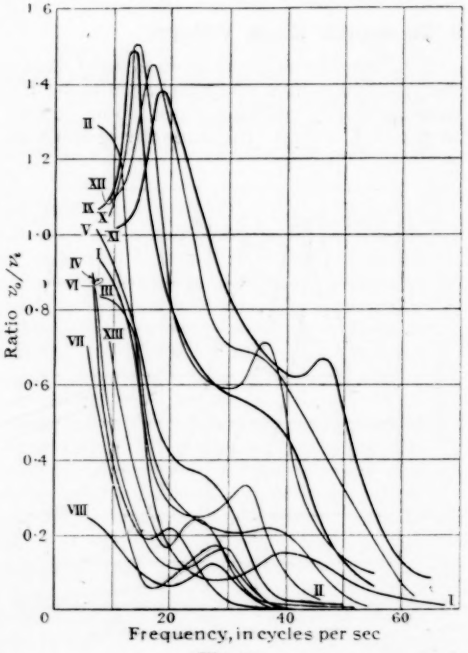


Fig. 11.

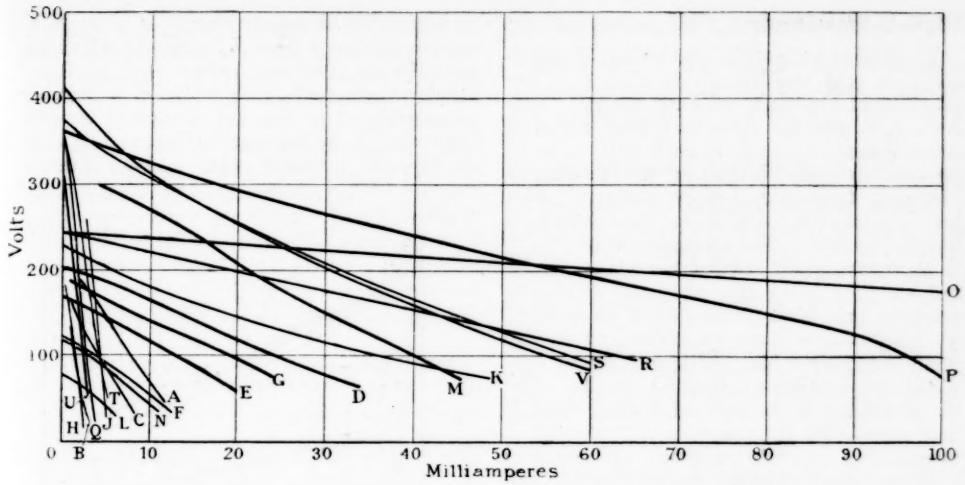


Fig. 12.

3. The useful output, expressed in mA for a fixed permitted voltage-drop, say, $33\frac{1}{3}$ per cent. from the initial voltage.

4. The audio-frequency impedance of the output circuit of the appliance measured at some stated frequency, *e.g.*, 500 cycles per sec.

Some idea of the extent of the variation of these quantities for a number of commercial appliances is shown in Table I., the name of the makers not being given. The variation of output voltage and current is also brought out in Fig. 12. These emphasise the wide variety in designs which are met with, and show that finality in design cannot yet be said to have been reached.

11. Measurement of Output Characteristics.

The load of an ordinary type of moving coil voltmeter rendering it nonpermissible, the use of a "Unipivot" galvanometer with a scale of 0 to 120μA is recommended with a series resistance of 2 megohms. A voltmeter of this type also enables a reasonably true measure to be made of the output voltages under working conditions.

TABLE I.

MEASURED OUTPUT COEFFICIENTS OF VARIOUS COMMERCIAL H.T. SUPPLY APPLIANCES.

Reference to Fig. 12.	Regulation for load of 1mA	Internal Impedance.	Effective output for voltage drop of $33\frac{1}{3}$ per cent.	Audio-frequency impedance of output circuit.
	%	ohms.	mA	ohms.
A	8.69	19,000	4.0	160
B	30.6	50,000	1.0	160
C	9.65	16,000	3.6	—
D	1.98	4,167	16.2	320
E	3.4	6,000	9.6	—
F	5.4	6,500	15.8	—
G	2.67	4,375	14.0	160
H	35.79	68,000	0.9	320
J	19.8	100,000	2.0	160
K	1.25	2,667	25.2	318
L	9.5	8,200	3.2	265
M	1.7	5,700	19.3	160
N	6.4	7,800	5.3	—
O	0.27	670	121.0	170
P	1.4	5,000	49.0	170
Q	26.7	100,000	1.3	490
R	1.1	2,500	34.0	47.5
S	1.8	6,800	23.0	47.5
T	16.7	60,000	1.9	145
U	27.0	80,000	1.2	152
V	3.1	13,000	16.0	85

NOTE.—The audio-frequency impedances tabulated in the last column are values corresponding to a frequency of 500 cycles per sec.

12. Grid Bias Supply.

In general terms the theoretical arrangement of grid bias shown in Fig. 1 is impracticable, especially on D.C. mains. With A.C. it is *possible* (provided double-wound transformers are used in each unit so as to provide complete insulation of the output voltages from the supply mains). This necessitates considerable expense which is hardly justified. The arrangement of Fig. 13 is therefore given, where a portion of the voltage drop along the resistance *R* can be used for grid bias. This should be shunted by additional by-pass condensers as shown, while other grid bias voltages may be provided by additional tapping points. The disadvantage of the method is that, since *R* is in series with the common H.T. supply, it provides a certain amount of coupling between the various stages. With too small by-pass condensers there is a serious risk of "howling" on this account. These condensers should preferably be not less than 1μF.

It is also noted by the authors that a very similar arrangement* has been proposed as a means of eliminating the effect of rippie without filter chokes and condensers. The principle is to inject into the grid circuit a

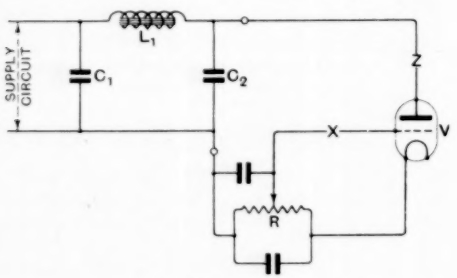


Fig. 13.

proportion of the total available voltage so that the ratio of anode voltage to grid voltage is equal to the amplification of the valve.

13. H.T. Rectifier Arrangements.

It is pointed out that the unilateral conductance of the valve is usually employed as a rectifier to supply the filter of an H.T. supply appliance from A.C. mains. Although an ordinary receiving valve—with grid and anode commoned—may be used, a number of special valves are now marketed for this purpose. They are usually designed to have a copious emission and a low internal

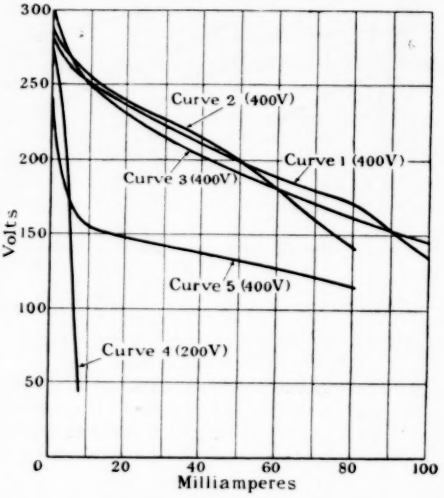


Fig. 15.

resistance, so that they may pass considerable fractions of an ampere without causing an excessive drop in voltage. Typical emission characteristics are shown in Fig. 14 (not reproduced). It is desirable that the total emission should, in general, be not less than 100mA. Output characteristics of several such valves are shown in Fig. 15, curve 5 being for a cold cathode pattern of rectifier.

14. L.T. Supply Appliances.

The use of the supply mains for filament lighting is simple but frequently costly. A simple series resistance to give the requisite drop will still produce disturbances as in the H.T. case unless a filter is used. Such resistance must be in the positive limb or the H.T. supply cannot be taken from the same source. A filter for the larger order of filament currents is expensive on account of the size of chokes and condensers required. Valves of lower filament consumption

* Due to G. M. Wright. British Patent 261110.

simplify the problem chiefly on account of the diminution in the size of chokes. The filaments can be joined in series, but this involves internal rearrangement of the set.

Fig. 16 is given as showing filtering arrangements for filament supply. The floating battery of Fig. 16 (*b*) is probably the most useful filtering arrangement, but still involves battery provision. A single stage of filtration can, of course, be used but with less effective results.

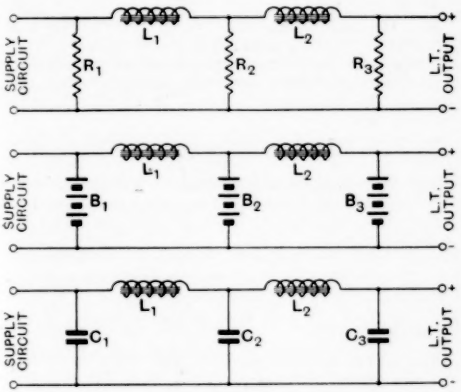


Fig. 16.

15. L.T. Supply Rectifiers.

If the source is A.C. a rectifier must be added as in the case of H.T. supply. The rectifying valves used for H.T. supply are, however, mostly unsuitable for providing sufficient current for L.T. supply. Generally the only available rectifiers are the electrolytic, gas discharge tubes, or solid chemical rectifiers.

It is the authors' opinion, however, that a really effective, efficient and economical type of L.T. supply appliance that can also be correctly described as a true "battery eliminator" has yet to be devised.

The more usually adopted arrangement, particularly for A.C. circuits, is a type of "trickle charger," the battery being automatically charged from the mains at a low rate when the set is not in use. Two batteries may be used combined with an automatic switching device so that one battery is charging while the other is applied to the set.

16. Substitutes for L.T. Supply Appliances.

Reference is here made to the recently developed principle of the independently heated cathode.

17. Miscellaneous Appliances.

The methods referred to here are (*a*) a generator driven from a convenient motive power, or electrically from a low voltage accumulator; (*b*) proposals for the use of voltages generated thermo-electrically from any convenient heat source. It is stated that many proposals have been made in this direction but that the method has not been practically utilised to any appreciable extent.

18. Precautions Necessary in the Use of Radio Supply Appliances.

With the direct electrical connection between H.T. and L.T. at the radio apparatus and in the supply mains, certain precautions must be taken to avoid risk of shock or of dangerous short circuits. A suitable insulated condenser must be inserted in the normal earth connection of the receiver, and properly insulated wire should be used for all connections of the supply appliance and the wireless set. Filter condensers should comply with the B.E.S.A. specification and the earthing condenser should preferably be of the 600 v. class. When the appliances are used on A.C. circuits, the use of double-wound transformers in the rectifiers should protect against short circuits from the mains, provided that the insulation of the transformers is of reasonable quality. If the appliance is metal-cased, the case should be earthed.

During the reading of the paper, demonstrations were given showing the effects of various elements of the filters referred to, especially in Figs. 7 and 10. Alternating voltages were applied to an amplifier and loud speaker, either directly or via the filter under demonstration, and the effects of variation of L_1 and C_2 (of Fig. 2) were shown for various frequencies. The existence of a secondary hump in a two-stage filter (*c.f.*, Fig. 11) was shown, along with its movement on change of the electrical constants. The effect of the input condenser was also demonstrated both without and with rectification.

DISCUSSION.

A lengthy and interesting discussion followed the reading of the paper.

The discussion was opened by **Lt.-Col. H. P. T. Lefroy,** who described a set, with which he had experimented, as an example of mains supply. The L.T. and H.T. were taken through separate chokes, resistances being used for smoothing. He strongly advocated the use of supply mains for convenience and economy.

Mr. W. J. Brown thought the paper went a long way in defining ratings, and discussed the need for knowledge of this. He suggested the third of the authors' proposed ratings as perhaps appealing most to the purchaser. Definition of the smoothing effect was also necessary.

Mr. N. Lea referred to the matter of output impedance. Considerable reaction existed before howling was set up. This was of importance at very low frequencies, especially with R.C. coupling. In rating, it was necessary to state the D.C. " regulation " of each output point, and the output impedance, at some stated frequency.

Mr. Watson discussed instability which might arise from the causes referred to in the paper. This would depend on whether the amplifier represented an overall negative or positive resistance. If it had a negative resistance it would oscillate. This could frequently be reversed by reversing one transformer. In the case of R.C. coupling improvement could be effected by grouping the stages in twos and supplying the groups by separate filters.

Mr. P. K. Turner suggested that the matter of filter could easily be dealt with by known details of the methods of filter design. As regards rating terms he suggested the milliamperes delivered at a stated voltage, and the voltage rise or fall per milliampere.

Mr. J. H. Reyner said that mains supply was now a practicable proposition. The input capacity was important in regulation, especially with single wave rectification. In rating there was also a need for specification as regards hum.

Mr. G. G. Blake thought that the convenience of mains operation would outrun the cost. He also discussed alternative methods of obtaining grid bias.

Mr. Scroggie dealt with the construction and design of choke coils. There was a lack of appreciation of the variation in the inductance of iron-cored chokes with current. He quoted several different cases of the variation with a stalloy core at different currents, and emphasised the need for attention to this.

Mr. Goodall discussed ripple tolerance, and stated that he had found a value of 0.02 volt, which he considered to be more of the order permissible than were the authors' figures. Rating should also indicate the maximum current to be drawn from the appliance.

Mr. P. P. Eckersley emphasised the need for high anode voltages, in the present state of loudspeaker design. He suggested attention to machine generation to work off A.C. or D.C. supply mains and to deliver the requisite H.T., L.T. and grid bias for wireless purposes. This could be made economically and gave scope for regulation and control. For A.C. supply of filament, he recommended a transformer with a potentiometer across the filament so that the grid lead could be joined to the electrical centre.

Mr. Lewis considered that the first condenser was not essential, even in A.C. A first choke was much more important, this practice reducing to a double stage filter without input condenser.

On the motion of the Chairman, **Major B. Binyon, O.B.E.,** the authors were cordially thanked for their paper.

Mathematics for Wireless Amateurs.

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C.

(*Continued from page 228 of April issue.*)

PART II.

1. Geometry and Trigonometry.

SOME of those who have waded patiently through Part I of this series will perhaps be disappointed that the next step will not bring into view the promised land of the calculus; but from the position we have so far reached only a partial view could be obtained. The calculus covers a wide territory. Some of its main lines of communication (to strain the analogy almost to breaking point) pass through regions we have not yet explored—in particular those of geometry and the closely-related subject of trigonometry.

Apart from its bearing on the calculus, geometry, as the study of space and space relationships, has a very close relationship with the problems of theoretical and applied electricity, much closer than might at first be realised. The coils, aerials, condensers, and other apparatus of applied electricity are themselves solid configurations in space, and their functioning is in many cases determined mainly by their "geometry." Also the close analogy that exists between the ideas of pure algebra and those of pure geometry make the latter an indispensable aid in analysis. The graphic representation of functions is an instance of this. The vector diagrams of alternating current theory are another, though in this case the analogy has a very definite physical basis. The representation of a sine wave of E.M.F. as a rotating vector is more than a convenient mathematical fiction. It expresses and symbolises the fact that the E.M.F. has actually or virtually originated in an armature rotating in space with the same effective angular velocity. In fact, the rotating vector can almost be regarded as an end view of the armature.

In view of these and similar considerations a brief account of some of the ideas that originated in the subtle brain of Euclid over two thousand years ago is essential in a course of mathematics intended for wireless amateurs of to-day. For the sake of brevity and compactness the writer is making, perhaps rashly, an attempt to cover the whole of the relevant field of trigonometry and geometry in terms of the vector ideas which have proved of such immense value in their application to specifically electrical problems. It will necessitate beginning at the beginning, but that is probably all to the good as far as most of the readers of this series are concerned.

2. The Straight Line.—Angles.

Geometry has the whole of space for its domain, but two dimensions will suffice for the scope of this series. We shall consider plane relationships only.

The simplest geometrical element is a point, and the next simplest a straight line, which Euclid defined as the shortest distance between two points. In conformity with modern views of geometry, a straight line will be considered as infinite in length unless specifically limited.

A single infinite line in an infinite plane has no describable characteristics except straightness and extension, but each of two such lines in an infinite plane has in addition a direction relative to the other. This relative direction is called the angle between the lines, and is conveniently described by means of letters in either of the ways illustrated in Fig. 1. The angle marked with a star will be called the angle AOB (written $A\hat{O}B$) or θ. Where a single symbol is used (generally a Greek letter) it must be inscribed in the angle as shown.

It is important to realise at the outset that the letter notation of geometry has a dual character In the first place it is used simply to identify certain elements for

reference. In the second, it functions as an algebraic symbol, standing for a number which measures in some specified manner the magnitude of the element. Thus the θ of Fig. 1 serves both to identify the angle $A\hat{O}B$ and to specify its amount, or magnitude. How this amount is to be measured will be considered later.

Apart from any system of measurement, an angle can be thought of as an amount of

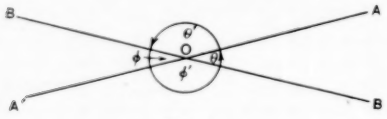


Fig. 1.

turning. Thus the line OB has to be turned through an angle θ about O as pivot in order to give it the same direction as OA. The two alternative directions of rotation (anti-clockwise and clockwise) suggest at once a sign distinction. It is almost universally agreed to consider an anti-clockwise rotation as describing a positive angle (as in Fig. 1) and a clockwise rotation as describing a negative angle. This conforms with the algebraic significance of the negative sign, for

$\theta+(-\theta)=0$, algebraically and geometrically.

It is obvious that the amount of turning represented by $\theta+\theta'$, *i.e.*, the amount of turning that brings OB into line with OB', BB' being a straight line, is a constant for all such pairs of lines. The angles θ and θ' are called "complementary," each being called the complement of the other. It follows that

$$\theta+\theta'=\theta'+\phi$$

so that

$$\theta=\phi$$

The angles θ and ϕ, θ' and ϕ' are called opposite angles.

If the line OA is rotated about O in a positive direction, θ will increase and θ' decrease, and since the sum of the two is constant a condition will be reached when

$$\theta=\theta' \quad \text{(Fig. 2.)}$$

The line OA is then said to be perpendicular to BB' and the angle θ (or θ') is called a "right angle."

The right angle is the basis of one system of measuring angles. It is divided into 90 equal rotations, each of which is called a degree. (The perverse spirit that seems to preside over the whole English system of weights and measures must surely have had a hand in this awkward choice.) A degree if further sub-divided into 60 minutes and a minute into 60 seconds. In this system a complete rotation is four right angles or 360 degrees, and a half rotation 180 degrees. Thus complementary angles are such that

$$\theta+\theta'=180°$$

and in practice the definition is extended so as to include the case in which either angle is greater than 180°, the other being correspondingly negative.

Later on another system for the measurement of angles will be described. This alternative system, though numerically not much more convenient than the degree system, has a less arbitrary basis. It cannot be fully explained, however, until we have some understanding of the great principle of geometrical similarity on which it is based.

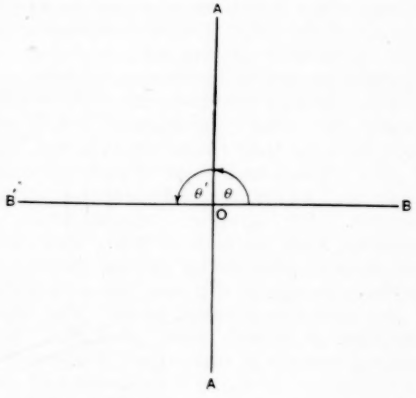


Fig. 2.

3. The Triangle.

Suppose now that a third line is introduced into our infinite plane (see Fig. 3). Each of the three lines will then acquire the additional characteristic of relative position as well as relative direction. (This is not

immediately relevant, but is introduced to emphasise the essentially relative character of position, and the fact that two other lines are required to specify it.

The figure bounded by these three coplanar straight lines is called a plane triangle. The sides can be described by means of the letter pairs AB, BC, CA, or more conveniently by the single letters shown in the figure.

Notice first that if the line $A'C'$ is turned about A through the angle α in the direction shown, then about B through the angle β and then about C through the angle γ, it will make a half revolution, the points A' and C' reversing their position with respect to B. Therefore

$$\alpha + \beta + \gamma = 180°.$$

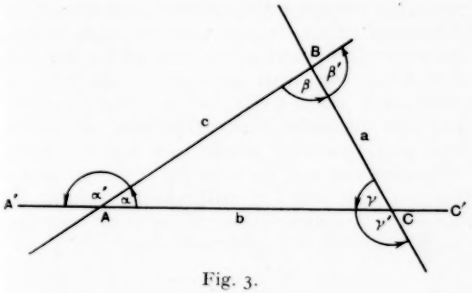


Fig. 3.

In words, the sum of the internal angles of a triangle is two right angles. Further, since

$$\gamma' + \gamma = 180°,$$

$$\gamma' = \alpha + \beta$$

and similarly for the other pairs of internal angles. The angles α', β' and γ' are called the external angles of the triangle.

Only one metric property of the sides can be stated so far. It follows from the definition of a straight line that

$$a + b > c \quad b + c > a \quad c + a > b,$$

i.e., any two sides of a triangle are greater than the third.

4. Parallels.

Suppose the line BC (Fig. 3) is rotated in a positive direction about B. The point C will move along $A'C'$, as shown in Fig. 4, and the angle γ will decrease continuously. As γ decreases the sides a and b will increase continuously. The relationship

$$\alpha + \beta + \gamma = 180°$$

will however remain true throughout. As

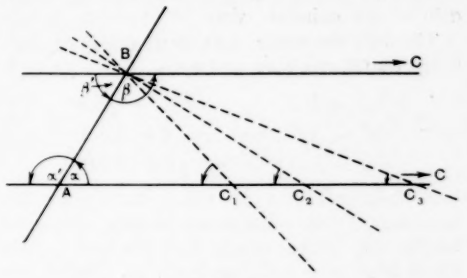


Fig. 4.

the rotation continues it is clear that a condition will be reached when

$$\alpha + \beta = 180°$$

and in consequence

$$\gamma = 0$$

In this condition the line BC is said to be parallel to AC. It will be shown later that a and b are then greater than any finite quantity however large, *i.e.*, the point C is at infinity. Since

$$\alpha + \beta = 180° \text{ and } \beta' + \beta = 0$$

it follows that

$$\beta' = \beta$$

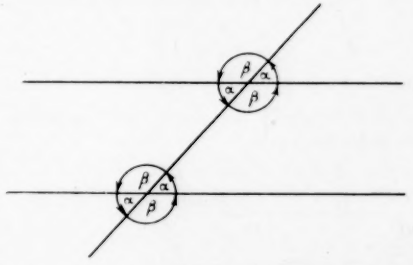


Fig. 5.

These are obviously general relationships, true for any pair of parallel lines and a third cutting through them both The angular equalities are as indicated in Fig. 5.

5. Equality of Triangles.

By the complete equality of geometrical figures is meant the equality in magnitude of all the corresponding elements, sides, angles, etc. A practical criterion of equality is that the one figure, placed on top of the other, will coincide with it at every point.

The two triangles ABC and DEF of Fig. 6 are equal in every respect if

$$\begin{array}{ll} AB = DE & A\hat{B}C = D\hat{E}F \\ BC = EF \quad \text{and} & B\hat{C}A = E\hat{F}D \\ CA = FD & C\hat{A}B = F\hat{D}E \end{array}$$

but obviously not all these conditions are necessary. For instance, if two pairs of angles are given equal, the remaining pair must also be equal (see Sect. 3). What are

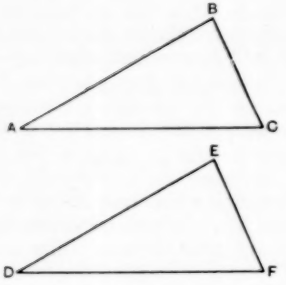


Fig. 6.

the minimum conditions that will ensure complete equality? There are three separate combinations of such conditions.

(*a*) Two sides and the included angle, *i.e.*,

$$AB = DE$$
$$AC = EF$$
and $$A\hat{B}C = D\hat{E}F$$

(*b*) One side and the angles not opposite to this side, *i.e.*,

$$AC = DF$$
$$C\hat{A}B = F\hat{D}E$$
and $$B\hat{C}A = E\hat{F}D$$

(*c*) Three sides, *i.e.*,

$$AB = DE$$
$$BC = EF$$
$$CA = FD$$

The first two are very easily proved by considering the second triangle to be, as it were, lifted and placed down on the first. The proofs are too simple to justify giving space to them. The third cannot be proved in this way, and will be deferred till later.

6. Geometrical Similarity.

The above discussion of equality brings us to one of the most practically useful and important ideas in the whole of geometry,

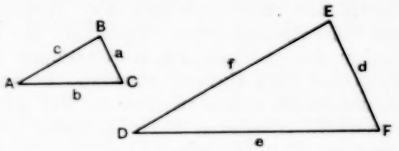


Fig. 7.

the idea of geometrical similarity. It is probably not generally realised that the whole science of trigonometry, with its applications to surveying, navigation and astronomy, is based on this one principle. The idea is concerned with the relation between equiangular triangles, *i.e.*, triangles of which the corresponding angles are equal. Such triangles are not necessarily equal in every respect, as Fig. 7 will show. There is, however, a definite metrical relation between such triangles, the relation being

$$\frac{a}{d} = \frac{b}{e} = \frac{c}{f}$$

The proof is not easy, but an outline of it will be given on account of its importance in all that follows.

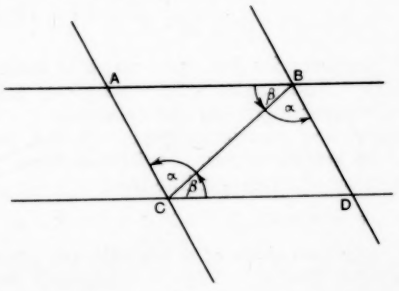


Fig. 8.

Consider first the diagram of Fig. 8, in which AB is parallel to CD and AC to BD. It follows from the properties of parallels that the angles marked with the

same Greek letter are equal. The triangles ABC and DBC, having the side BC in common and these angles equal, are equal in every respect, by the preceding. Therefore

$$AB=CD \quad \text{and} \quad AC=BD$$

This is the first step. Now look at Fig. 9, where B is the middle point of AC, BD parallel to CE and DF parallel to AC. By applying the result just proved it is easy to show that $AD=DE$. This result can be extended as shown in Fig. 10. If the line AB is divided into n equal parts by the parallels to BC, then AC will a'so be divided into n equal parts or "segments." Returning now to Fig. 7, the smaller of the two triangles can be drawn inside

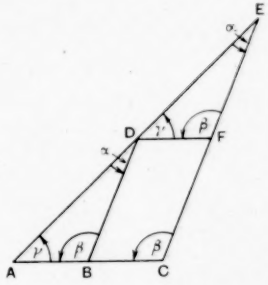


Fig. 9.

the other, as shown in Fig 11, the line BC being parallel to EF, in virtue of the angular equalities assumed. If the ratio of AC to AF is expressed in its lowest terms as the fraction m/n, AF can be divided into n equal segments by lines parallel to, and including, BC. The line AC will be divided into n equal segments by n of these lines. It follows from the preceding that AB and AE will be similarly divided by these parallels, so that

$$\frac{AB}{AE}=\frac{m}{n}=\frac{AC}{AF}$$

Similarly by withdrawing the smaller triangle so that B coincides with E, it could be shown that

$$\frac{AB}{AE}=\frac{BC}{EF}=\frac{CA}{FA}=\frac{m}{n}$$

i.e.,

$$\frac{a}{d}=\frac{b}{e}=\frac{c}{f}$$

It follows from the properties of fractions proved in Part I of the series, that

$$\frac{a}{b}=\frac{d}{e} \quad \text{and} \quad \frac{b}{c}=\frac{e}{f}$$

both of which equalities are included in the form

$$a:b:c=d:e:f$$

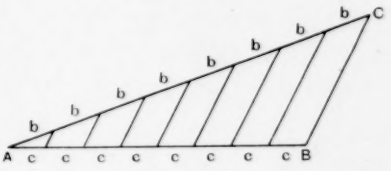


Fig. 10.

This means that the *relative* magnitudes of the sides of a triangle depend only on the shape of the triangle, and will be the same for all triangles having two angles of the one equal to the two corresponding angles of the other. That is the important conclusion to remember. Two triangles related in this way are said to be similar. The trigonometrical ratios which will now be described are no more than an expression of this similarity in the particular case of right-angled triangles.

7. The Trigonometrical Ratios.

Consider the right-angled triangle shown in Fig. 12. Any other right-angled triangle containing the angle of θ will be of the same

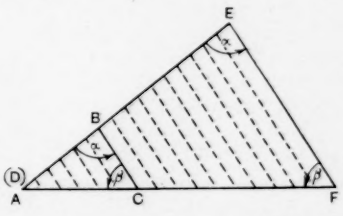


Fig. 11.

shape as this. Therefore the relative magnitude of the sides, *i.e.*, a/b, c/b and a/c, and the reciprocals of these ratios or numbers, will depend only on θ. They can therefore be considered as functions of θ and tabulated

for various values of θ. Special names, tabulated below, are given to these numbers.

Apart from the reciprocal relationship,

Ratio.	*Name.*	*Abbreviations.*
height/hypothenuse	sine	sin
base/hypothenuse	cosine	cos
height/base	tangent	tan
hypothenuse/height	cosecant	cosec
hypothenuse/base	secant	sec
base/height	cotangent	cot

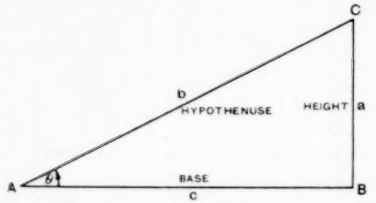


Fig. 12.

it is clear that these ratios, being functions of θ, must also be functions of one another, and will therefore possess certain inter-relationships. One is immediately obvious from their definition, for

$$\frac{sin}{cos} = \frac{\text{height}}{\text{hypothenuse}} \Big/ \frac{\text{base}}{\text{hypothenuse}} = \frac{\text{height}}{\text{base}} = tan$$

Another important relationship will be proved later.

In practice the above definitions of the trigonometrical ratios are extended, as shown in Fig. 13, to cover any value of θ up to four right angles. The positive angle θ is the amount of anti-clockwise rotation of AC from AX, and $sin\ \theta$ is BC/AC, etc., etc. Similarly for the remaining quadrants.

Without further qualifications, however, an angle such as θ', where $AB = AB'$ and $BC = B'C'$ in magnitude, would have the same ratios as θ. The ambiguity is avoided by a sign convention relating to the constituent lines of the ratios. The sloping line is considered to have no sign at all but all other lines are considered to be measured away from the centre A, and are taken as positive in the directions AX and AY and negative in the directions AX' and AY'. Thus (Fig. 14), if the lines have the magnitudes shown by the small letters, BC and ED are interpreted as the number a, BG and EF as the number $-a$, and so on. This convention results in the following signs for the ratios in the various quadrants :—

sin	+	+
cos	—	+
tan	—	+
sin	—	—
cos	—	+
tan	+	—

The table need not be memorised, as it is easier to apply the sign convention direct in any given case.

Remembering that a negative angle is a rotation in a clockwise direction, it is easy to see that

$$sin\ \theta = -sin\ (-\theta)$$
$$cos\ \theta = \quad cos\ (-\theta)$$

and therefore

$$tan\ \theta = -tan\ (-\theta).$$

Further, there will be certain simple relationships between the ratios of angles that differ by positive or negative multiples of a right angle. For instance,

$$sin\ \theta = \quad cos\ (90° - \theta)$$
$$cos\ \theta = \quad sin\ (90° - \theta)$$
$$sin\ \theta = -cos\ (90° + \theta) \text{ etc., etc.}$$

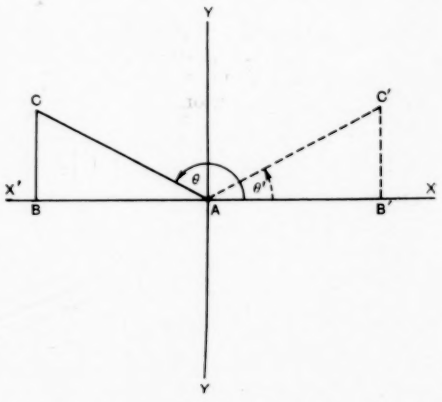


Fig. 13.

These, again, need not be memorised, as it is much easier to draw the appropriate lines in a quadrant diagram in any given case.

Given that

$$sin\ \theta = n$$

θ may be described as the angle having the sine n. This is written, conventionally

$$\theta = sin^{-1}\ n.$$

It should be noticed that whereas $sin\ \theta$ is a single-valued function of θ, *i.e.*, given θ there is only one value for its sine, $sin^{-1}\ n$ on the other hand is many valued, has in fact an infinity of values, for if θ be the smallest angle having the given sine, $\theta + r \times 360°$, r being any integer, will all have the same sine. Similarly for the other "inverse" functions.

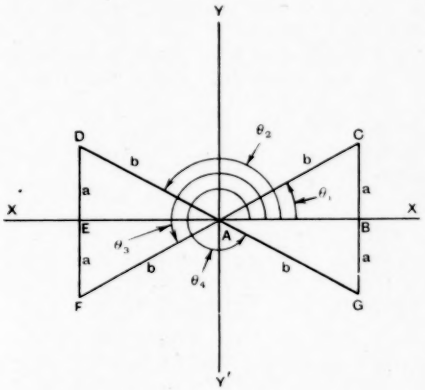


Fig. 14.

There is no need to illustrate the sine and cosine of an angle graphically, for these curves will already be familiar to all students of electricity in connection with wave forms of alternating currents. Before leaving this part of the subject, however, some important special cases should be noted. Referring to Fig. 12,

$$sin\ \theta = a/b \qquad cos\ \theta = c/b$$

Now as θ tends to zero, b tends to equality with c and a tends to zero, so that

$$sin\ 0 = 0 \qquad cos\ 0 = 1 \qquad tan\ 0 = 0$$

Similarly

$$sin\ 90° = 1 \qquad cos\ 90° = 0 \qquad tan\ 90° = \infty$$

$$sin\ 180° = 0 \qquad cos\ 180° = -1 \qquad tan\ 180° = 0$$

etc., etc.

Examples.—May, 1927.

1. Two angles of a triangle are 17° and 83°. What is the third angle ?

2. An irregular pentagon is a five-sided figure with equal sides. Prove that the sum of the internal angles is 540°. (Join the corners of the pentagon to a point inside it.)

3. The sides a, b, and c of the triangle in Fig. 7 are 4, 5, and 9 ins. long respectively. The side f of the triangle DEF is 10 ins. What are e and d ?

4. Show that :—

$$cosec\ \theta\ tan\ \theta = sec\ \theta$$
$$sec\ \theta\ cot\ \theta = cosec\ \theta$$

5. Given that $sin\ 50° = .766$, and that $cos\ 50° = .643$, find the values of : $tan\ 50°$, $sec\ 50°$, $cosec\ 50°$, $cot\ 50°$, $sin\ 140°$, $cos\ 220°$, $tan\ 320°$, $tan\ -50°$, $sin\ 40°$, $sec\ -40°$.

6. Find the value of $(sin\ 50°)^2 + (cos\ 50°)^2$.

Answers to Examples in March Issue.

1. (*a*) $1 - x + x^2 - x^3 + x^4$

   (*b*) $a^{-1} + \frac{1}{2} x^5 a^{-6} + \frac{3}{2\cdot 5} x^{10} a^{-11} + \frac{1\cdot 1}{1\cdot 2\cdot 5} x^{15} a^{-16} + \frac{4\cdot 4}{8\cdot 2\cdot 5} x^{20} a^{-21}$

   (*c*) $1 + 3x + 6x^2 + 10x^3 + 15x^4$

2. This depends on the fact that

$$n\ (n+1)\ (n+2)\ \ldots\ (2n-2) = (2n-2)\ (2n-3)\ \ldots\ n.$$

3. 2.9931.

4. 1.9520.

7. Prove by expansion of e^{-1} and grouping of the terms in pairs.

Design and Construction of a Superheterodyne Receiver.

By P. K. Turner, A.M.I.E.E.

IN setting out to write a description of some experiences in building supersonic sets, I should like to emphasise the fact that this is simply a "description." It does not pretend to be an authoritative or didactic article. Frankly, I feel that my experience of this type of set is not sufficient for that purpose, while at the same time the results may be of interest. Secondly, I should like to make it clear that the views expressed herein, and the designs suggested, express my own ideas only, and not necessarily the views of the organisation with which I am connected.

When I first considered the prospect of investigating this type of set, I had in mind one very clear-cut idea, which was supported by the admirable article by Armstrong in the Journal of the I.R.E., of October, 1924, that in most supersonics there were too many valves eating their filaments off in semi-idleness. I had always insisted in other sets that my valves should earn their nourishment very fully, and I wanted to find out whether they could not be made to do so in a supersonic.

The layout of a typical supersonic receiver would comprise eight valves: an oscillator, two detectors, three I.F.s (intermediate frequency) amplifiers, and two L.F. amplifiers. Of these, only five are actually amplifying.

Before one can go into the possibility of economy, it will be as well to investigate shortly the work to be done by each type, if only to clear up our ideas.

The Oscillator.

The first duty of this is, obviously, to maintain quite steady oscillations which can be added to those coming in from the distant station. The frequency is determined by the necessity of producing beats of a definite "intermediate frequency" to which the intermediate amplifier is tuned.

The proper amplitude of the steady oscillation is a more difficult matter. We are, of course, dealing with typical heterodyne reception. It is known that if the steady local oscillation is *less* powerful than the incoming wave, the strength of the resulting beat is more or less proportional to the local oscillation. Obviously then, we will keep the local current at least equal to the incoming. It has commonly been said that if the local oscillation is greater than the incoming one, the resulting beat is proportional to the latter. But Appleton and Taylor, in the Journal of the I.R.E. of June, 1924, and Colebrook in *E.W. & W.E.*, of May, 1925, have shown that owing to the peculiarities of detectors the matter is more complicated than this, and that the resulting beat is a maximum for any given incoming signal if the local oscillation bears a certain definite (but variable) proportion to it, of the order of five to twenty times as strong. The matter is further complicated by the fact that a variation of strength of the local oscillation, if done by adjustment of the oscillating valve itself, and not merely by adjusting its coupling to the detector, may alter the proportion of harmonics generated by it. This is a most important matter, as will be seen later, when the matter of harmonics is discussed more fully.

The First Detector.

Here we meet with one of the two great difficulties of the supersonic—or any other set. That is, from the point of view of one writing about them. For the rectifier, whether valve or crystal, is undoubtedly quite difficult to investigate, though it is easy enough to write about in a popular (and probably inaccurate) manner.

Let us clearly understand, to begin with, why the first detector is needed. One often hears it rather casually stated that "the mixture of currents at two different frequencies produces beats of a frequency equal to their difference and that the beats are amplified," or some such statement. Now,

firstly, such a mixture does not produce beats of the difference frequency, and secondly, one cannot amplify a beat. The correct way to state the case is to say that " the sum of two equal currents of differing frequencies is equivalent to a current of the average frequency, modulated at a frequency of *half* the difference." Although it is modulated, it is still a high frequency current, and cannot be amplified by an amplifier tuned to the difference frequency.

But if it is rectified, the case is different. Here again, there seem to be some confused ideas. It is not quite correct to assume that if one puts in a pure alternating current to a rectifier one gets a simple direct current out of it. Just exactly what one gets out depends on the rectifier ; but with a simple alternating input of frequency f, one will almost certainly find the output to be a mixture of : a direct current, an alternating current of frequency f (that of the input), one of frequency $2f$, and probably others of frequency $3f$, $4f$ . . . etc. If, however, the input is fully modulated, for the same maximum amplitude the output will contain a smaller D.C. than before, the difference being made up by a current of twice the modulation frequency, and others of four times, etc., this.

Now suppose that the input to our detector consists of a local current of frequency f_0 (o for oscillator) and a distant current of frequency f_d, then this is equivalent to (*a*) a current of f_0, because the original f_0 current is stronger than the f_d one ; (*b*) a current of frequency $f_0+f_d/2$, modulated at the frequency $f_0-f_d/2$.

The output from the detector will then contain

(1) from (*a*) and (*b*) a direct current ;

(2) from (*a*), currents of f_0, $2f_0$, etc. ;

(3) from (*b*), a current of frequency twice $f_0-f_d/2$, and others of 4, 6, 8 . . . times this frequency ;

(4) from (*b*), a current of frequency $f_0+f_d/2$, and others of 2, 3 . . . times this.

There may be others, and some of these may be small, but the above is typical of the "mixed bag" flowing in the output circuit.

If then f_0 and f_d are two fairly high "radio" frequencies close together—say 1,000 and 900kC, we shall have the following :—

(1)	from (*a*) and (*b*) . .	D.C.
(2)	from (*a*)	1,000,000
		2,000,000
		3,000,000, etc.
(3)	from (*b*)	100,000*
		200,000, etc.
(4)	from (*b*)	950,000
		1,900,000, etc.

If we tune the output circuit to 100,000 cycles, and couple it to an amplifier which is also tuned to this frequency, we can pick out that component (marked with a * above) ; and this is what is done.

It is to be noted that if the local current (*a*) is stronger than the distant one (*b*), all those components derived from (*b*) will be proportional to (*b*).

Our 100kC output is among these ; and if (*b*) was modulated at audio-frequency, this component will faithfully reproduce the modulation.

The essential point to remember is that the detector output is by no means one of a simple difference-frequency, but is a complex current containing a whole series of frequencies. The D.C. and the "high" frequencies (2) and (4) will not get much further consideration, though they may cause trouble by "beating" among themselves. But the series of harmonics (3) of "intermediate" frequency must be looked into.

It is true that they do not interfere with the final result, for they are stopped by the amplifier, which is tuned to one frequency only. But it must be remembered that the object of the supersonic is to "reduce" all incoming signals to the same intermediate frequency, by varying the local oscillations. Thus in the case above, a signal of frequency 1,000kC would be welcomed by a local current of 900 or 1,100kC. The rectifier output will contain (among others) a component of 100kC, as required. But suppose one were using 900kC as local frequency, and another signal of 950kC came along. Then there would be in the output a frequency of 50kC which would be duly stopped by the tuning. But there will also be the harmonics of 50kC, and the second harmonic is 100kC, so our 1,000kC signal will be jammed, if the second harmonic is strong enough.

Further, if the local oscillator is set to 950 or 1,050kC, there will again be 50kC and its harmonics in the output, and the second harmonic will be amplified. Nor is this the only trouble, for the local oscillator itself almost certainly sets up harmonics, which in the course of searching for one station may set up beats with another. Later on, in describing my first efforts at a set, I will give an actual example of what may occur. For the present, enough has been said to show that harmonics in the local oscillator, or set up in the process of detection, may cause much confusion if they are at all strong, and should therefore be avoided.

Obviously then, the most important points in the first detector are (*a*) there should be comparatively few harmonics set up by it; (*b*) it should be reasonably sensitive to small input.

The Intermediate Amplifier.

The duty of this is—in theory at least—a simple one. It is to select from among the various currents flowing in the circuit of the first detector one definite one, and amplify it. Unfortunately, in the case of a supersonic set for broadcast reception, we are confronted with the fact that we have to amplify, not a single wave, but a band; while there are such possibilities of extreme selectivity that we are tempted to try to separate stations very close together; we are asked therefore to give a large and even amplification to a certain band of frequencies, while "cutting out" all others.

It may be of interest to explain here in a few words just *why* the supersonic is so essentially selective. It is due to the fact that a *difference* of frequency appears unchanged after the first detector, and is a larger percentage of the small intermediate frequency than of the large original frequency; and selectivity depends on percentage differences.

Thus, take a 300-metre signal modulated at 1,000 cycles. This acts as if it were a mixture of three currents, at 999,000 cycles, 1,000,000 cycles and 1,001,000 cycles respectively. If we set to beat with it a current of 900,000 cycles, we shall have in the output (among others) currents of 99,000, 100,000 and 101,000 cycles. Thus the modulation is preserved unchanged. Now suppose an interfering station on 297 metres. This is 1 per cent. away from the first, and is hard to tune out. But 297 metres is 1,010,000 frequency: our beating current of 900,000 cycles will set up in the detector output a current of 110,000, which is not 1 per cent. off but 10 per cent. off that which we are trying to get. In fact, the separation (in percentage) of the two stations is multiplied by the ratio of the intermediate to the incoming frequency.

The action of the supersonic principle itself, then, is to multiply the separation between stations. To take advantage of this, we must still have a selective intermediate amplifier. But if it is one fraction too selective, it will begin to cut off the higher notes which form the extreme edges of the band of wanted signals. Thus, taking the case mentioned above—300 metres—but modulated at 5,000 frequency and "converted" to 100,000 cycles by the first detector, we find that the amplifier should

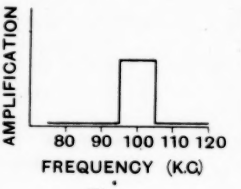


Fig 1.

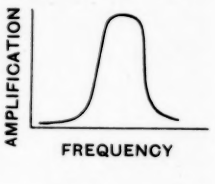


Fig. 2.

On the left, the ideal resonance curve; right, the type obtained in practice.

have the same overall performance for all frequencies between 95,000 and 105,000, but should not work outside these limits. We want a resonance curve like Fig. 1. Actually, such a curve cannot be got; all resonance curves are more or less of the type of Fig. 2. But it is an interesting point that by employing several stages of amplification, each one fairly selective, a much more "flat-topped" curve can be got than by putting up one very selective stage. This idea was rather fully developed by the present writer in *E.W. & W.E.* of October, 1925. Later, we will take up the actual design of the amplifier to get the required selectivity.

As to the actual frequency to be chosen for the intermediate amplifier, there are conflicting requirements which lead to a compromise. In order to get maximum selectivity, the frequency should be low; but this is not very important; for the total selectivity is limited, as just pointed out; the limit can

easily be reached with an intermediate frequency of 100,000. The frequency must, however, be considerably lower than (say one-third of) the lowest frequency to be received, which means not more than 50,000 if Daventry is to be received.

If, however, the frequency is *too* low, there are increasing difficulties due to the I.F. being too near the modulation frequencies. Practically, 30,000 (10,000 metres) is getting near the limit.

The Second Detector.

Although the main function of both detectors is to rectify, the properties required of the first and the second are widely different in detail. For example, the second detector

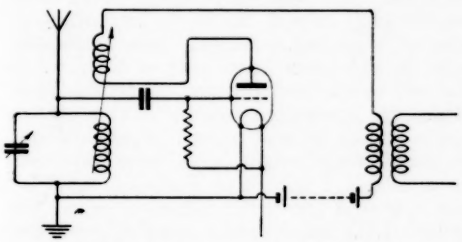


Fig. 3. *This simple circuit is not successful for a supersonic oscillator, as it is too far from being tuned to the incoming wave.*

is seldom required to work on very small input, while the first is. Again, harmonics (beyond the second) set up in the first rectification have to be tuned out in the amplifier, and are a nuisance; but harmonics in the second are actually heard as distortion, and must be avoided at all costs. In general, the second detector works much as does the one detector of an ordinary set; but the fact that it has a long-wave input (3,000 to 10,000 metres) may have its effect on our choice of type.

The L.F. Amplifier.

Here we are on familiar ground—but even here we may find in details that the fact that the input to our detector is of lowish frequency may have to be considered.

Possible Economies.

Now, having considered the duties of the various parts of the set, we must consider how valves can be saved. The possibilities are fairly obvious. One or both of the detectors may be crystals; if the first detector is a valve it may be made to act as oscillator also; the H.F. valves—if any—may be made to do duty as I.F. also; some of the I.F. valves may be made L.F. also.

A crystal as first detector was tried by the writer in the first attempt ever made at supersonic work, and was fairly successful. But it was given up because it involved the use of a separate oscillating valve, and it was found more efficient and little more difficult to make the oscillating valve detect as well.

The use of a combined H.F. and I.F. valve is a feature of the Radiola set. In order to avoid the necessity of an extra tuning control, a "semi-aperiodic" transformer is used. Personally, I do not favour the idea. *Pace* Captain Round (who, I know, holds the opposite view) I do not think that an H.F. amplifying valve is a necessity in a supersonic. Since this type of set is above all one for simplicity of handling, it seems a pity to introduce another tuning adjustment, and a more or less untuned H.F. coupling does not appeal to me, even if the stage can be got by a valve that is doing I.F. work as well. Incidentally, a fair experience of reflex working leads me to suspect that it will be none too easy to get stable ***and*** efficient combined H.F. and I.F. amplification.

When, however, we come to reflexing I.F. to L.F. valves, the matter is rather more favourable. Firstly, it is certain that there will be I.F. and L.F. amplification in the set. Secondly, one has no variable tuning to face. The matter is not quite so simple as reflexing high frequency valves to audio-frequency, as I.F. and L.F., being nearer to one another, are not so easy to separate. But in practice I have found it quite successful.

A First Attempt.

After a certain amount of thought on these lines, and a few preliminary experiments with a one-valve "frequency converter" put in front of an existing long-wave reflex amplifier, I proceeded to design the first set.

One point was found quite definite in these first experiments: that any attempt to reflex the first I.F. valve and make it do L.F. work as well was likely to produce instability.

No definite reason could be stated, but the general conclusion was that it was due to the fact that the input circuit of this valve already contained such a mixture of frequencies from the detector that the addition of audio-frequencies upset its digestion. I do not propose to describe this set in detail, for its good points were used in the later set, but it will be, I think, advantageous to show its bad points, as a lesson in what to avoid. Shortly, it was a four-valve set: combined detector and oscillator on the second harmonic principle; 3 I.F.s; crystal second detector; and two of the I.F.s also as L.F.s.

The first troubles that turned up were due to the harmonic oscillator. For the sake of completeness I must outline the action of this. If, as in Fig. 3, we try to make the

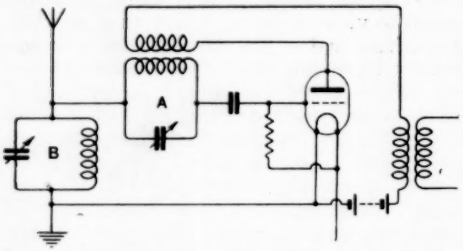


Fig. 4. *An alternative to Fig. 3. Its disadvantage is interference between circuits A and B, which is avoided by tuning A to half its normal frequency.*

first valve oscillate and detect in the usual way, we lose efficiency because the aerial circuit must be tuned to the oscillator frequency and not the incoming frequency, and these are not quite close together as in ordinary heterodyne reception.

It was soon suggested that one should use, as in Fig. 4, an additional circuit *A* tuned to the oscillator wavelength, keeping the aerial tuned to the incoming frequency. But although the two frequencies are too far apart for efficient use of the circuit of Fig. 3, they are near enough to one another for the rejector action of the circuits *A* and *B* to be felt; each tends to choke the other and the slightest change in either alters the circuit conditions for the other.

It was Huth's suggestion that the circuit *A* should be tuned to *half* the required frequency. Thus, say we want to beat at 900kC against a 300-metre signal in *B*, instead of tuning *A* to 333 metres we tune it to 666. The oscillating valve, as usual, has its output harmonic currents, and the second harmonic is of the required frequency of 900kC (333 metres).

In practice there was one serious disadvantage. I could not get a valve to generate *only* the fundamental and second harmonic—it invariably set up a whole series. When I first tuned the set over the broadcast band (at about two miles from 2LO), London kept on coming in. It was not flat-tuned; in fact it was dead sharp at each position; but there were 11 positions at which it could be got.

How this occurred is as follows: First, the deliberate encouragement of the second oscillator harmonic (by using extra bias on the grid) caused the third—and others—also to be strong. Second, these conditions also caused extra harmonics *of the I.F.* to be set up in the process of rectification. Third, the second harmonic of 2LO itself was quite strong at that range. I worked out in detail what might have been expected, as a table. I give here a similar table for the case of a 300-metre incoming signal and 100kC I.F., which gives simpler numbers. To show the idea, take the first case. If the oscillator is set at 300kC, meaning to use its second harmonic (600kC) to beat against 500kC or 600 metres coming in, its third harmonic sets up 100kC beats with our 300-metre station.

If it is set to 950 metres, the third harmonic sets up 50kC beats; but since extra harmonics are set up in rectification, the second of them is 100kC, and gets through the I.F.

In Table I, the first two columns give wavelength and frequency of the oscillator. The two "proper" positions are starred. The third shows which harmonic of the oscillator is effective for that setting; the fourth shows whether it is the fundamental or the second harmonic of the incoming signal that is concerned; the fifth shows the frequency of the resulting beat, and the sixth gives what harmonic of this (generated in rectification) is audible.

After some experience of this it was definitely decided that in any future sets, steps would be taken to keep harmonics down to an absolute minimum!

Another trouble which arose was due to the fact that the last audio-frequency valve

like the others, was an I.F. valve as well. This was puzzling at first. The symptom was instability whenever the output was brought up to full loud-speaker strength, which at once suggested overloading of the valve by the combined I.F. and L.F. input. This was tested out by putting in an extra big valve, with such voltages as to make sure that there was no overloading in the ordinary sense of the word. The trouble was still there.

TABLE I.

Oscillator.		Oscillator Harmonic.	Incoming Harmonic.	Difference kC.	Harmonic Heard.
λ m	kC				
1,000	300	3	F	100	F
950	317	3	F	50	2
930	322	3	F	33	3
870	344	3	F	33	3
850	350	3	F	50	2
815	367	3	F	100	F
670*	450	2	F	100	F
630	475	2	F	50	2
620	483	2	F	33	3
580	516	2	F	33	3
570	525	2	F	50	2
545*	550	2	F	100	F
475	633	3	2	100	F
460	650	3	2	50	2
455	656	3	2	33	3
442	678	3	2	33	3
435	684	3	2	50	2
430	700	3	2	100	F
333	900	F	F	100	F
317	950	F	F	50	2
		2	2	100	F
	967	F	F	33	3
	975	2	2	50	2
	983	2	2	33	3

and six others above 1,000kC.

Next it was thought that it might be due to slight curvature of the first reflex valve characteristic throughout, which may cause a sort of super-modulation, as I have explained at length in "The Perfect Set" (*E.W. & W.E.*, October, 1924, – August, 1925). This was tested out by putting a picked valve in the first position, which did not cure it.

Eventually it was concluded that when the output of the last reflexed valve was very large, and its arrangement was that of Fig. 5, as in this case, there would be enough audio-frequency voltage across *L* to cause an appreciable component to appear in the throw-back transformer besides that due to the rectification of the I.F. In this case, of course, there is audio-frequency reaction, and a howl will be set up. Accordingly, it was definitely decided that in future sets the last valve should be a pure L.F. power valve.

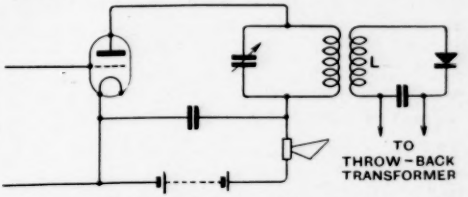


Fig. 5. *When reflexing an output valve, we find trouble due to the L.F. voltage across* L.

The third trouble found was a general "trickiness" due to stray capacities and couplings. It was seen that careful consideration must be given to layout.

The Second Set.

On the basis of the experience gained a considerable time was devoted to the detail design of the second set. It was decided straight away that this should comprise five valves: a "detoss" or combined oscillator and detector; 3 I.F.s; crystal second detector; two of the I.F.s to be used for L.F. also; and a final power valve.

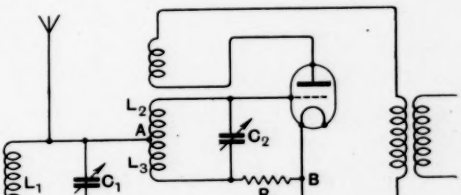


Fig. 6. *A well-known bridge "detoss" circuit which is not really satisfactory.*

Since the harmonic "detoss" system had shown such serious disadvantages, some alternative had to be found, and some sort of bridge circuit seemed to be indicated. At the time when this was being settled there was a popular circuit known as the

"Tropodyne," which is shown in Fig. 6 (of course, a frame can replace the open aerial and aerial tuning coil). The theory of this can perhaps be better seen from Fig. 7. It

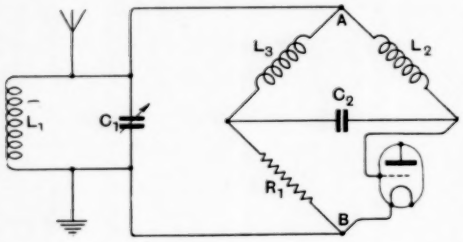


Fig. 7. *The circuit of Fig. 6 redrawn, to show why it cannot be balanced accurately.*

will be seen that incoming signals set up a voltage across L_1C_1, which is passed to the valve *via* L_2; L_3 and R_1 are in shunt, and cause a slight loss of energy which is not

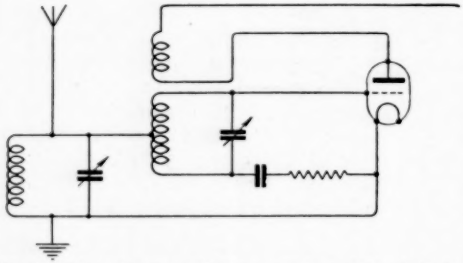


Fig. 8. *This gives some improvement over Fig. 6, but it is still impossible to maintain the balance.*

important. On the other hand, if $L_2=L_3$ and R_1=the input impedance of the valve, these four form a balanced bridge; at any frequency of the oscillator the potentials at A and B are identical, and although voltages are induced into L_2 and L_3 by the reaction coil, thus causing oscillation in the circuit $L_2L_3C_2$, none of this gets back to the aerial. The oscillation frequency is controlled by C_2, and the aerial tuned to the incoming signal by C_1.

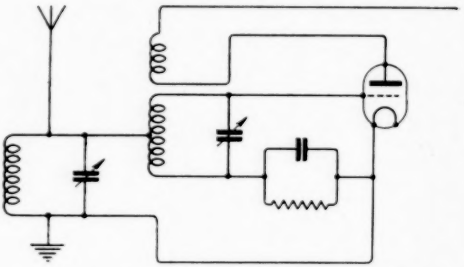


Fig. 9. *A possible modification to Fig. 8, subject to the same criticism.*

Unfortunately, however, this simple circuit is far from perfect, for in practice the bridge cannot be balanced. The input impedance of the valve is of the nature of a capacity and resistance in series, and such a combination cannot ever be balanced by a pure resistance. It can be balanced by a capacity and resistance in series, or by a different capacity and resistance in parallel, so that one might hope to get better results by the circuits of Figs. 8 and 9. But there is still a serious difficulty. The input impedance of the valve is not a constant thing. It varies with the filament, grid, and anode voltages, with the setting of the reaction coil, and even perhaps with the strength of incoming signals. Hence the balancing capacity and resistance can only represent a mean value; and the bridge may often be unbalanced.

(*To be* ***continued.***)

The Solar Eclipse and its Effect on Radio.

Some Suggestions for Research During This Year's Total Eclipse of the Sun.

A Lecture before the Radio Society of Great Britain by Captain H. de A. DONISTHORPE, delivered at the Institution of Electrical Engineers, on Wednesday, 23rd March, 1927.

IT gives me the greatest pleasure to be before you once again this evening after an absence of some three years in the U.S.A., but it is with some sorrow that I note the apparent falling off in interest by the radio amateurs of this country in their science, a fact which, for some unknown reason, seems to have been brought about by the advent of broadcasting here.

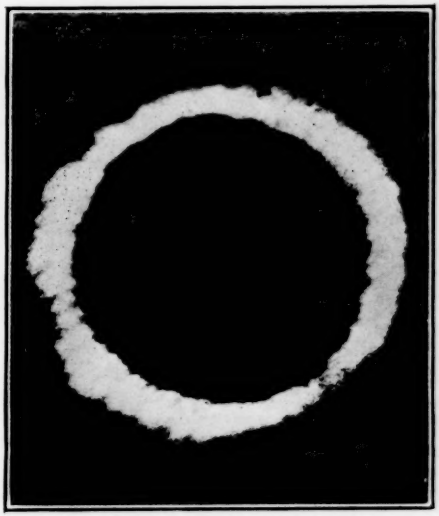
In America there has been no falling off in the numbers of radio "fans," who still find much to maintain their interest in radio matters.

Looking back at my records I find that it is about four years since I read a paper before you, and on that occasion I spoke on one of the latest developments then—namely, the four-electrode valve. Since that time radio has made great strides in all parts of the world.

After a careful study of the conditions in America as compared with ours I have come to the conclusion that we have little to learn about radio from the other side of the Atlantic, although I will say their broadcasting is more entertaining than that to be found here. Broadcasting over there, on the other hand, as I have stated before, has had no effect on the activities of the radio experimenter, who is still as zealous as ever over his work.

A few weeks ago I attended an informal meeting of this Society, when it was deplored that there was little to-day for the amateur to do in the line of research. I, however, disagree with that statement. At that meeting that very able and enthusiastic follower of our activities, Captain Ian Fraser, also seemed to be of the same opinion and considered that there was little left for us to experiment upon, bar the perfecting of each of our individual receivers, or the hunting for far distant broadcasting stations. It is my intention, therefore, this evening to put before you some points which outline a very definite line of research for all radio amateurs to follow during the coming June.

During 24th January, 1925, it was my good fortune to witness in New York City one of the marvels of the universe, namely, a total solar eclipse.



The sun during total eclipse showing the corona.

We here are to see such a phenomenon this year providing we are able to take a day's holiday and travel to the Midlands, and I can assure you that it will be a journey worth while, always of course providing the climate conditions are favourable.

In the New York eclipse conditions were ideal and precisely at 9 a.m. a part of the

city was plunged in complete darkness after a prolonged twilight period.

One of the interesting visible points about the eclipse was its definition. As you know, the streets of New York are divided into parallel blocks and numbered, and whilst in the 'nineties only a semi-eclipse was noticeable from 110th Street onwards to another definite street totality was witnessed.

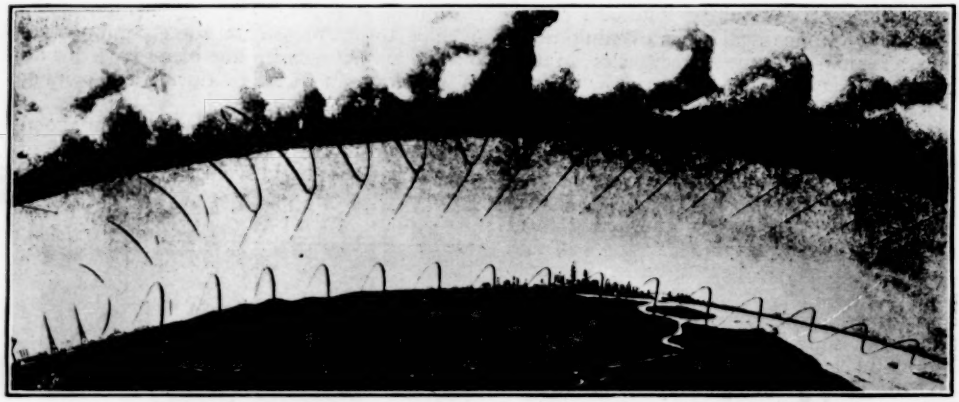
It was the wish of many that the city should not be supplied with artificial light at the critical time, but the New York police knew better of their underworld to allow this, and the general public were therefore disappointed by the presence of full night lighting throughout the eclipse.

At the precise moment of totality those in the track of totality witnessed the unusual sight of all the stars suddenly coming out like a second night, together with the wonderful sun's corona.

You will no doubt by this time be inquiring what all this has to do with radio reception or the propagation of electro-magnetic waves.

It is no doubt presumptious on my part to mention the effects known as "night effects" to a body of radio enthusiasts, but that is the connection between radio and a solar eclipse. This "peak" reception, as you all know, has always been a phenomenon that has been studied by all radio engineers and experimenters, and it is therefore my intention to detail some of the effects that we noticed in America as far as radio is concerned during their total eclipse, with a view to suggesting a line of research for all the members of this Society.

Positively speaking, we all know that the sun's rays have a very definite effect on radio waves, and we also know that this effect is closely associated with that mysterious phenomenon called the "Heaviside layer." Perhaps for the purpose of clearness it is desirable at this stage of my paper to briefly refresh our memories as to the theory of the "Heaviside layer" seeing that this phenomenon is so clearly connected with the *raison d'ètre* of my talk.



By courtesy of the Scientific American

The ground path and the upper reflected path of the wave.

Radio engineers of to-day consider that there are two wave paths possible for the waves emitted from a transmitter, one the ground path and the other the upper wave path. During the night time the upper path is subjected to alterations due to a variation of the ionisation of that upper layer. These variations cause the direct path of the wave alternately to reinforce or oppose the direct path of the wave. Now it is during the night or darkness period that the ionisation occurs which causes an alteration in the speed of this indirect wave. This alteration, however, is not uniform, and consequently the progress of the wave is disturbed in a most complicated manner.

Darkness is caused by the eclipse; it is therefore reasonable to associate this phenomenon with the night effects associated with radio, especially having due regard to the

fact that the darkness period does not occur in its usual diurnal frequency.

Before I actually discuss the details of the American tests I want to make it quite clear that this talk is not intended to be a complete work on the subject—in fact, that would be impossible due to the short time I have had available to prepare it—but rather as a general outline with the object of acting as a guide to our experimenters along which they may direct their efforts.

By courtesy of the Scientific American

The total eclipse in America, 24th January, 1925.

Luck as usual favoured America during the eclipse and the scientists were not hampered by bad atmospherical conditions, visibility was excellent as far as the optical observers were concerned, and the atmosphere was free from static for the radio experiments.

Dealing only with the radio side of the question, it can be said there were some variations and contradictions as far as the results are concerned, which were due possibly to purely local disturbances or accidental faults of local receivers.

Ignoring these isolated cases and taking an average of the results obtained, it was found—and I want you to take careful notice of these—that the results differed according to the position of the transmitter and receiver relative to the track of totality.

The experiments were conducted with the aid of certain broadcasting stations and these transmitted on waves which by previous experience gave the greatest night effect and were confined to continuous wave transmission. It was also arranged as far as possible for the receivers to be spaced from the transmitters at distances where maximum fading had been noticed. These receiving sets were tested for five days prior to the eclipse in order to note whether they were consistent in their readings.

I do not propose to go into the details of the receivers which actually were modified superheterodynes coupled to strength recording apparatus. A further opportunity will be available to discuss this apparatus at one of the later informal meetings of this Society. It will be of interest, however, to learn that in some cases it was quite possible for the human ear to detect the variations of the signals received from the special stations.

During the brief interval of totality of a solar eclipse, it will be interesting to note that the sun's rays are cut off from an area of several thousand square miles whilst for

several hours there is semi-darkness over a considerably larger part of the earth's daylight surface.

In summarising the results noticed I cannot do better than quote Mr. Pickard, of the

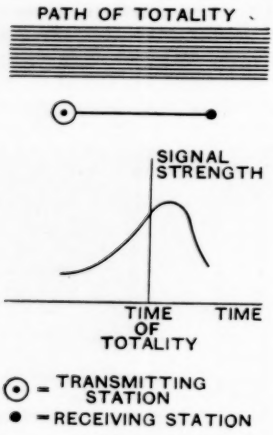


Fig. 1.

American Wireless Speciality Apparatus. He says: "For those wavelengths and distances, which are better at night than day, the eclipse improved reception; whilst the wavelengths and distances which are normally better by day than night the eclipse decreased reception."

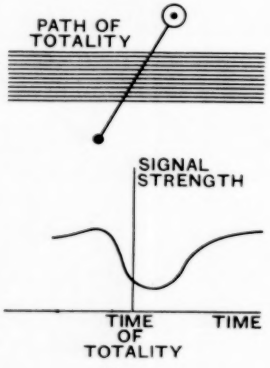


Fig. 2.

The results, as I have mentioned before, differ with the relative positions of the transmitter and receiver, and these I will now detail.

Case I.

When the listener and the transmitter were on the *same* side of the shadow there was a gradual *increase* in the signal strength beginning about twenty minutes before totality and falling off again by about ten minutes after totality. (Fig. 1.)

Case II.

When listener and transmitter were on *opposite* sides of the shadow there was a *decrease* beginning a few minutes before totality and lasting until after totality. (Fig. 2.)

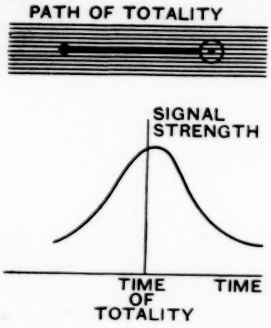


Fig. 3.

Case III.

When both listener and transmitter were *within* the shadow there was a relatively sharp increase in signal strength practically coincident with totality at the transmitting station. This fell off rather quickly after totality was over. (Fig. 3.)

Case IV.

When the *listener* was *in* the shadow and the transmitter *outside* there was a falling off shortly before totality with an increase after totality, falling away again afterwards. (Fig. 4.)

The eclipse occurred at a time in the morning when the sun's rays had not entirely done their work on the ionised layer, as otherwise greater variations would have probably been noticed.

As far as our eclipse is concerned, which takes place on 29th June, it occurs at an

unfortunately early hour, namely 5.23 a.m., which is difficult from a domestic point of view as well as at a time when the sun's rays will barely have made their presence felt on the ionised layer.

The track of totality extends from the North of Wales, Carnarvon to Hartlepool. The B.B.C. have very kindly consented to get their engineers up early that morning and special signals will be sent from Daventry and other stations the particulars of which will be disclosed later. The Radio Corporation of America has also kindly consented to co-operate and to arrange to send some special signals from their stations and they now only wait to hear from me as to our details when they will make the necessary arrangements. We ourselves can

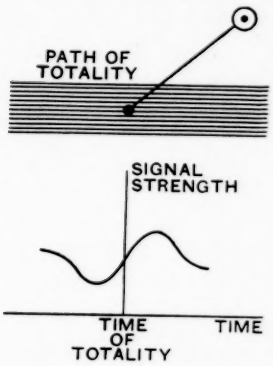


Fig. 4

enlist the services of the T. and R. members to send some special signals for listeners on their short wave stations.

I venture to suggest in conclusion that it is necessary for our Society to organise itself so that we can collect in a comprehensive manner all the data obtainable and make the necessary arrangements for listeners and transmitters within and without the path of totality.

I therefore suggest that a committee be formed for this purpose. I understand that our Mr. Cooper is to attend a conference of the Department of Scientific and Industrial Research in connection with this forthcoming eclipse, and it will be interesting to hear later the results of this conference. If there is anyone here this evening who is connected with that Board, it would be pleasing if he will say a few words afterwards as to their suggested programme.

My talk this evening was originally intended for the informal meeting of 22nd April, and I therefore suggest to the Chairman that since that date is now vacant it might be useful to use it for a general discussion on this subject and for the formation and issuing of instructions for our research, providing, of course, it is decided that the Society is going to participate in the work of elucidating the effects of this eclipse on radio. I offer these latter suggestions for your consideration.

DISCUSSION.

Admiral Sir Henry Jackson : We are very much indebted to Captain Donisthorpe for his very interesting lecture, and it is very opportune, as it takes time to prepare and organise any observational work that is going to be done during the eclipse. He mentions that we had a conference at the Department of Scientific and Industrial Research with a number of persons interested, not only our own staff, but others representing the commercial wireless companies in the country and the B.B.C. We have not got out all our details yet, but they will be published, so I will leave that matter for the moment. The results of the New York eclipse are very interesting indeed, and, so far as I can see, they quite uphold the theory which is accepted about the effect of the ionised layer. When the moon is between the sun and the earth, the sun's radiation and corpuscles cannot reach it, and this tends to raise the height of this ionised layer for a time. That would make a great difference, especially to these amazing skip distances on short waves. The T. & R. Section will deal with that, and it will be really useful if they will organise a good series of observations. There is one point which Captain Donisthorpe did not mention and which I had never looked into until a few days ago. It is that the visible shadow of the moon on the earth is over a different place from that of the shadow of the Heaviside layer. In the case of the eclipse this year, if we imagine that the Heaviside layer will be about 60 miles up at the time of the eclipse, then the path of the eclipse on this layer in Great Britain will be above a track from the Bristol Channel to the Wash, instead of from North Wales to Hartlepool. Consequently, we are selecting the disposition of our receiving sets to meet this point, that is farther to the south than we should have done if the two paths had been the same. This is a point worth remembering ; there is not the slightest doubt about it, and I think the effect is more likely to be noticed on that southern path than it would if the northern path is taken. In order to be on the safe side, we are arranging for fairly long signal distances and are going well each side of the paths. Mr. Cooper attended a meeting of the T. & R. Section and said he would try to organise a few signals. In fact, he is suggesting a transmission from Iceland, and, I think, from

Caterham. I do not know whether the owners of the transmitters will be able to agree to it, but we shall then be well on both sides of the lines, whichever line is taken. A point to be remembered is that if a large number take part in it they must choose their wavelengths so that there will not be interference and jamming between each other. Another point we settled was that we should have time signals, and I think the B.B.C. are arranging to give time signals from all the stations which will be working that morning, every quarter of an hour. I think this ought to be good enough for those taking an active part in the above observations, if they get the Greenwich time signal—six dots—every quarter of an hour. We are going to try to have long waves, short waves and broadcasting waves, and the results on the various wavelengths recorded. Some very good results have been obtained recently with regard to the height of the Heaviside layer. The height can be calculated very accurately from the fringes which are photographed, and we hope to be able to get two sets of photographs from two different stations across the band. I think Captain Donisthorpe has given us something to think about, and I hope that advantage will be taken of what he has said.

The President: We have present to-night Mr. Hope Jones, the expert on time signals, who has already written to me on this subject, making certain suggestions as to some of the steps the Society might take. I hope he will say something now.

Mr. Hope Jones: The programme of time signals which the B.B.C. will be asked to transmit on the morning of 29th June is by no means fixed yet. The Royal Astronomical Society, representing the astronomers generally, have not yet prepared their formal request, which the B.B.C. have been good enough to indicate will be favourably considered. Admiral Sir Henry Jackson has mentioned that the six dots will be transmitted at 6 o'clock and at 6.15, and doubtless they will also be transmitted at 6.30 (Summer Time), but it is quite on the cards whether there will not be a much more elaborate programme of time signals during the actual period of totality. That is the one thing that astronomers can time; they cannot time the first contact, but they can time the beginning and the end of totality with exactness, and it has been suggested that for the three minutes from 6.22 to 6.25 we might have a continuous series of seconds dots, which would mean 180 of them. That is obviously open to one objection, that you will be confused with the counting unless you have an announcer—I think our B.B.C. announcers are capable of anything—a man who, without risk of mistake, calls out in staccato tones "5," "10," "15," and so on, with every five dots, and it may be that something of that kind will be seriously proposed. I think the question for this meeting (and for the adjourned meeting which Captain Donisthorpe has suggested should be held on 22nd April), is whether such time signals really will be useful as a means of making observations on signal strengths. I am not at all sure that these dot-seconds, of very short duration, are good for the purpose. The special time signals will doubtless be transmitted from 2LO and from Daventry, and also perhaps, if desired, from Liverpool, the Leeds-Bradford Station, and from Newcastle.

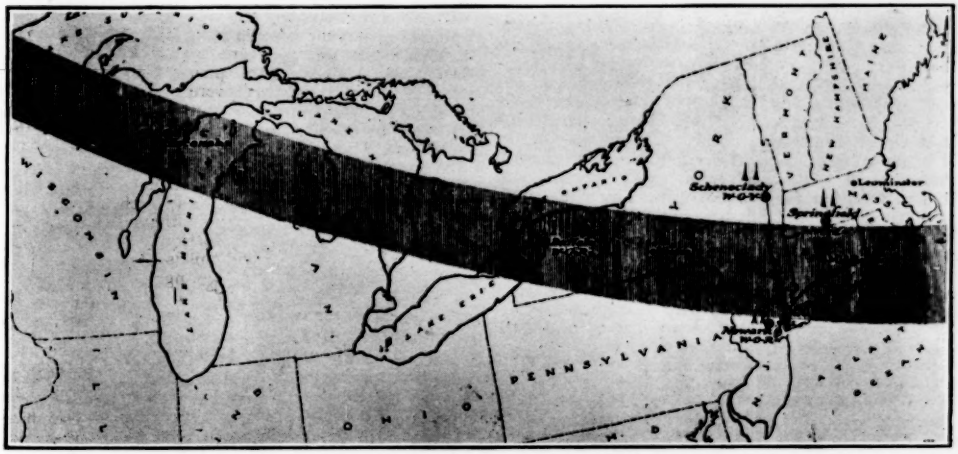
Mr. Bevan Swift: Captain Donisthorpe has enabled us to visualise what might occur during the eclipse. Looking at it from the amateur rather than the professional point of view, we can imagine the Heaviside layer in a very distorted form with quite a big bump on it, a condition which, of course, is normally never reached under the sun's rays, because the raising of the Heaviside layer at day time is a much more even occurrence, whereas during an eclipse, when the sun's rays are confined to a comparatively small portion of the ether, a very unusual effect must be produced. From the short wave point of view, we all know the difference between 45 and 23 metres. On 45 metres we get wonderful, though, it must be admitted, not consistent, effects at night time, whereas 22.5 or 23 metres is an effective wavelength for transmission in the day time. How is the solar eclipse going to affect that peculiar phenomenon? There must be a mean between the two, obviously, when we must get something of each. Therefore, we must be able to obtain some result such as that, which will be of tremendous value in judging the fading effect, and it would be of interest to arrange our tests partly on 45 metres and partly on 23 metres, so that we could see if there were any material appreciation on the one wavelength and any material diminution on the other. With regard to the question of skip distances on short waves, we all know that some stations are infinitely bad to receive from, that is, they do not happen to come in the tangent of the angle of reflection which is commonly supposed to exist. Whether that angle will be altered by the peculiar distortion of the Heaviside layer it is hard to say, and this is a point which our tests might very well be arranged to investigate. There is only one other point I want to raise, and that is with regard to Mr. Hope Jones' excellent suggestion as to seconds dots, and his reference to the difficulty of counting them. I would remind him of the old method adopted at the Eiffel Tower, of leaving out every tenth dot.

Mr. Maurice Child: With regard to these short wave tests, whilst, of course, they should be carried out, it is also important for us to bear in mind, as Sir Henry Jackson has already indicated, that for more or less localised observations round about the British Isles we want to use rather longer wavelengths as well. It would appear that, by working over the British Isles with such short wavelengths as those mentioned by Mr. Bevan Swift, we should not be likely to get very good results. The skip distances could come in, and we should not be likely to get contact. I do not mean that we should not use them, but I am suggesting that we should also get some very valuable data by using intermediate waves of, say, 70 metres and 100 metres, and even 125 metres, and so on. I think we should ask the Postmaster General to allot several wavelengths on that particular morning. Although Captain Donisthorpe rather deplored the fact that this eclipse takes place at such an early hour, I think really we can be very thankful that it is to take place at that time, because the B.C.L. people, who would otherwise interfere with the scientific work, will be in bed. I cannot conceive of anything

more unfortunate for the scientific aspect of the thing than to get all the B.C.L.'s interested in it. They will heterodyne each other, and the influence on these particular wavelengths on which they know from experience they can get their local stations would be simply terrible, I should think. Mr. Hope Jones made rather a useful suggestion with regard to time signals, and, if it is of any interest, I would suggest the possibility of doing the sort of thing I did two or three years ago when I was listening for atmospherics periodically in connection with the organised tests for which Dr. Eccles made himself responsible. The method is to mark a number of dots down in a line on a piece of paper, with a space between each, and to tick off each dot with a pencil as you hear it, so that you do not have to worry about the number. It is quite easily done. You simply mark the number of dots on paper corresponding to those transmitted and tick each one off as you hear it, and also make a little mark against any particular dot if at that point you hear anything phenomenal in the way of atmospherics or any other signal variation. Then, by counting the dots afterwards, the exact time at which a particular phenomenon occurred can be determined. Alternatively, I would suggest the method mentioned by Mr. Bevan Swift, namely, of leaving out the dot at each period of ten seconds. There is still another method, however, and that is to superimpose a note of slightly different pitch on to the one already being sent, say, at every ten or twenty seconds. If, however, you prepare a sheet of paper beforehand with the dots marked on it, it will not be necessary to send out a special signal at all; I did not find any difficulty with that method.

Mr. Hope Jones: If I may be allowed to speak again with regard to time signals, I would point out that it would be a little difficult, with the existing apparatus at the Observatory, to arrange a system by which the dot could be left out at every tenth second, or some such interval as that. The omissions would have to be effected by hand. I need hardly say that whatever time signals are sent out have to be absolutely correct, to 1/100th of a second. With regard to Mr. Child's remarks as to the facility with which the dots can be counted, if you have them marked on paper and follow them with a pencil, I might say that the person to whom the time signals are sent is primarily the astronomer in the field. He is busy with his telescope, spectroscope and other things, and he rather looks forward to hearing an audible signal whilst his mind, his eyes and his fingers are engaged in other work.

The President: I should like to ask Captain Donisthorpe one or two questions. In the first place, I should like to ask what wavelengths were employed in America at the time of the eclipse? I should also like some information as to the nature of the signals sent out. I take it that the mere recording of the signals themselves is only half the work; the strength of the signals requires also to be recorded if we are to have complete information. I have not heard it stated this evening, but I take it that some Department, perhaps the National Physical Laboratory, is taking steps to do all that, and what the members of the Society should do, and should do in order to assist the investigation and to justify the existence of the R.S.G.B. as a scientific body, is to get as much information as can be afforded them, and as much direction as they can, as to what they should do in order to get the most useful information and the best results. Captain Donisthorpe made a very useful suggestion, that on 22nd April, when the paper he has read to-night was intended originally to have been read, a discussion should be opened



Path of the total eclipse, 24th January, 1925, showing the distribution of the stations which participated in the tests.

in connection with this whole matter, so that everybody in the Society who is interested in it may hear a little more about what the conditions are, and in what way they can best help to get all the information, in tabulated form, that is necessary for working out the results after the event. He has also suggested that a small Committee should be set up by the R.S.G.B. to look into the matter, but I hope we shall have both the Committee and the discussion, because I think that probably the discussion will be of more use than the Committee; very often discussions are more useful than Committees. At any rate, I am sure that any of our members who can assist and co-operate with the people who are officially carrying out the experiments will render great service. I am not clear what is going to be done with regard to members of this Society or others sending out signals on their own account, but I am quite clear that if not regulated in some way it will confuse matters very considerably. I will now ask Captain Donisthorpe to reply.

Captain H. de A. Donisthorpe, replying to the discussion, said: Referring first of all to Admiral Sir Henry Jackson's remarks—the point about the relative positions of the two different paths, the one of totality and the other of the Heaviside layer—I have not heard of this before, but I think it is a most interesting point. I do not remember it being referred to in America during the experiments there. There is just one point I should like to mention to Mr. Hope Jones in connection with the remarks he made, which might interest him. One of the tests was carried out with telephony, and there was a stenographer taking down the signals at the transmitting station, and another at the receiving station. There were very accurate clocks both at the transmitting and the receiving stations, and as a certain word was transmitted, the time was taken at both stations to see whether there was any difference. If the wavelengths referred to by Mr. Bevan Swift, *i.e.*, 23 and 45 metres, are used, I think there will probably be some interesting results which will be characteristically different. I will repeat the words used by Mr. Pickard to suggest my remark, namely, "For those wavelengths and distances which are better at night than day, the eclipse improved reception, whilst for the wavelengths and distances which are normally better by day than night the eclipse decreased reception." Concerning our President's questions, the signals were sent out on the usual broadcasting bands; 491 and 379 were the wavelengths of the two broadcasting stations, and there was one long wave station sending out at 3,500. In some instances the signals were sent out on telephony, and the others were tone modulation.

Mr. Maurice Child: There is one little thing that a lot of us could quite easily do on the morning of the eclipse. If we are very lucky we may get something on our receivers, and it would be very interesting to know if there is any variation in the intensity of atmospherics during the eclipse. It is well known that on the Mediterranean at daylight there are atmospheric disturbances, and they might possibly be repeated in this part of the world. At any rate, it would do no harm to make a few observations in that direction.

Captain H. de A. Donisthorpe: In one particular instance at the period of totality, certain atmospherics of a rather strong nature were observed by a ship at sea, which blotted out signals, but about five minutes afterwards they disappeared. I do not know if that was the only instance recorded.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

That Audio-Transformer Problem.

To the Editor, E.W. & W.E.

SIR,—Mr. I. A. J. Duff has, in his letter in your February issue, made a number of comments on this problem, which, in my view of the matter, are open to considerable correction or criticism.

Since all theory results from practical experiment in the first instance, it has always seemed to me that an admission of a difference is an admission of incomplete knowledge or visualisation of the subject in question. In the present subject, the fundamental principles of which *are* so exactly known, can we not banish such differences ?

I think Mr. Duff will eventually see that his statements to which I took exception, and which he repeats as " still true " and " theoretically true " but modified in practice, are not intrinsically true at all—he will see that higher ratio transformers (lower primary inductance) can, as referred to by Mr. E. Green (October issue) with advantage be used with lower impedance valves because the impedance may still be equal to that of the valve at the nearly lowest note required and the amplification on all notes greater, and not because " intercapacities and leakages come in and upset one's theory."

In my original letter, I ought perhaps to have stated more clearly in the early stages that the principle of equality refers to comparison at one given frequency, as I see that Mr. Duff in his fifth paragraph is following Mr. Hall in making comparisons of a nature beyond the scope of that principle as I intended to convey it.

Remembering that frequency is a physical quantity of a very fundamental nature, let us clearly distinguish between the two divisions of the audio-transformer problem, viz. :—

(*a*) Effects at any one given frequency due to variations of other quantities ;

(*b*) Variation of these effects when the frequency is varied in certain defined circumstances as regards other quantities.

In regard to both it should be noted that because an amplification figure at a high frequency is greater than the optimum figure for a low frequency, it does not follow that it is even approximately the optimum figure at that high frequency.

There was no intended reference to (*b*) in my original letter, except in my last paragraph. It is a big subject which has already received duly large attention in various published articles.

In regard to (*a*) the question at issue is this :—

Concerning variation of transformer windings, do we, with a valve and transformer combination, get maximum overall volt-amplification at the given frequency when the effective impedance of the primary is the utmost possible, or do we get it in some other circumstances, *e.g.*, in those of approximate equality of that impedance with that (the anode A.C. resistance) of the valve ?

Mr. Albert Hall, supporting the original statement of Mr. Duff, says that we get the maximum when that impedance is of the utmost possible value. I cannot understand why they should hold this view, because the ampere-turn effect of a winding in series with a fixed resistance on a given overall P.D., which winding is made progressively finer and finer, ultimately decreases. That which takes place in the anode impedance of a correctly biased valve is, within reasonable valve limits, accurately represented by considering a pure resistance of amount equal to the impedance or anode A.C. resistance of the valve to be placed in series with that anode impedance and an overall P.D. of amount μ times the P.D. applied to the grid to act upon the combination.

It would seem that Messrs. Duff and Hall are not cognisant of the principle of a fixed and variable impedance in series on a given P.D. by which maximum activity (volt-amperes) occurs in the variable impedance when it is *equal* to the fixed, a result which is only slightly modified by the presence of hysteresis, eddy current and parallel capacity effects or by the fact that the resistance of the variable winding is not in exact proportion to its inductance. In this connection may I, Sir, particularly emphasise that the condition of equality of variable impedance with that of fixed impedance for maximum power (watts) in the variable impedance is only a *particular case*. In passing I would like to remark that a realisation of this fact under the correct conditions would perhaps clear up the difficulty between Messrs. E. Green and Holt-Smith. The necessary condition in all cases is that the power factors or phase angles of the variable winding and of the combined impedance remain substantially constant, or what is the same thing, the winding resistance, except when relatively unimportant, remains reasonably proportional to the inductance, and the parallel capacity, when present, also varies to suit. The principle admits of a very neat diagrammatic proof.

What, therefore, is, as twice admitted by Mr. Duff, true of the output transformer, is also true of the stage transformer, the variation in the former case occurring by loading up the transformer and in the latter by varying the winding fineness, the inductance being approximately proportional to the square of the number of turns. Valves with similar constants are required for the two cases, but with considerably less capacity (possible grid potential swing) in the stage case.

Mr. Duff accuses me of a " colossal howler " as a result, I fear, of an imperfect grasp of some of the basic principles with which we are concerned and of not clearly appreciating the postulated basis of variation of the quantities involved, in particular

the fact that variable valve conditions are not in question. He himself makes the error of interchanging the fixed and variable impedances and still thinking of the effect in the now fixed impedance. Naturally the effect in the *fixed* is greatest when the variable is of zero impedance. Also, when he changes the valve, is its impedance the only thing he alters? And can he show a case of increasing the *power* output by so doing as he would have to be able to do to be consistent?

My original qualifications concerning the variation of R and X were sufficient to render Mr. Duff's comments thereon unnecessary, but in any case it makes very little difference if R is widely disproportional to X because R is always small in relation to the total resistance or reactance.

Because variable valve conditions are not in question the ρ parts of Mr. Duff's 1 and 2 are of no import. If in 2 he means $X^2 + R^2$ to vary he makes the error of ignoring the effect of this on σ the transformer ratio.

In what sense is it correct to say that "a nice topped curve" is gained "by picking a σ to suit the valve"?

Mr. Duff says that Mr. Holt Smith gave a different angle to the discussion. How does he explain Mr. Holt Smith's instance of increased amplification when the winding fineness is reduced?

It is not correct for Mr. Duff to say that "one big firm" agrees with him—he has only had the personal support of Mr. Albert Hall. I feel that he has re-entered this discussion emboldened by the support he has received into saying some things perhaps without full self-conviction.

Finally, Sir, may I say that to describe my part in this discussion as "rushing into the fray" is far from the truth. A large amount of thought has been given to the matter, and though certain points are open to reasoned criticism, which I whole-heartedly invite, and in which connection it will be remembered that statements cannot always, for space reasons, be made *exactly* correct I do not think I am guilty of any "colossal howler."

E. Fowler Clark,
Derby. B.Sc., B.A., A.M.I.E.E.

Sir,—From the remarks of Mr. E. Fowler Clark, B.Sc., B.A., A.M.I.E.E., in your March issue regarding the above matter, he would appear to have mixed up the requirements necessary in a good high frequency transformer-coupled amplifier, with the quite different requirements of a good low frequency amplifier.

In the case of H.F. transformer coupling, the maximum amplification is provided when the valve and transformer primary impedances are equal, owing to the fact that the energy in the transformer primary is then a maximum, and consequently there is the maximum transfer of energy from the primary to the secondary windings, these being, of course, quite elementary considerations. The case of the low frequency amplifier is fundamentally different, in that one does not require to amplify one particular frequency enormously, but to amplify all audible frequencies to as nearly as possible the same extent.

It should be very easy to see that when a transformer primary is connected in series with a valve, one has two impedances in series, and the alternating impulses provided by the valve are impressed across these impedances in proportion to their relative values and phase. From this it follows that if the two impedances are at any particular frequency equal to one another, the proportion of the amplified voltage applied to the primary of the transformer is equal to $\sqrt{0.5} = .707$ of the valve amplification factor.

If the transformer impedance at any particular frequency is made infinitely great with respect to that of the valve, almost the whole of the amplified voltage produced by the valve is applied across the transformer primary terminals.

All transformers have resonance peaks where their impedance is to all intents and purposes infinite, and consequently, at such peaks, the whole of the amplification factor of the valve with which they are used is made use of.

If the impedance of a transformer can, by any means, be made very great at all other audible frequencies, it is very obvious that the voltage across the transformer primary will not vary appreciably.

From the foregoing, it follows immediately that the ideal condition is to obtain the highest possible impedance at all frequencies, and since it is comparatively easy to get a high impedance at, say, 2,000 cycles, even in a poor transformer, it is essential for the inductance of a transformer and its corresponding impedances to be as great as they possibly can be at the lowest audible frequencies. So that, even though the impedance does increase above those frequencies, the amplification does not increase.

The secondary winding merely steps up the voltage applied across the primary, and whilst capacity effects may be, and frequently are, present, which cut off the higher notes to a great extent (owing to the effective impedance of the transformer primary being reduced), this deficiency can be allowed for in the design of a good transformer, such as the one obviously referred to in Mr. Fowler Clark's insinuation regarding certain recent advertisements.

It is interesting to observe that transformers built on the assumption that the primary impedance is as high as possible at the lowest audible frequencies, actually do give far superior results to these in which this fundamental consideration is not followed.

Failsworth. J. Baggs.

H.T. and L.T. from a 250 Volt D.C. Supply.

To the Editor, E.W. & W.E.

Sir,—A few points arise out of the paper by A. Robertson (*E.W. & W.E.*, p. 111, February, 1927) which might be constructively criticised from the practical point of view.

The writer has at present over 300 installations at work off the mains on all sorts of receivers in over 30 towns.

The criterion of silence is in these cases the commercial one of complaints and their elimination.

It is not often that one has the advantage of a double circuit tuner when fitting in mains units but for obtaining absolute silence a double circuit

is more efficient than any combination of two condensers and choke. There are, of course, simpler arrangements of double circuits which are just as efficient as that shown in Fig. 1 (as regards silence) but with the advantage of requiring only one tuning adjustment.

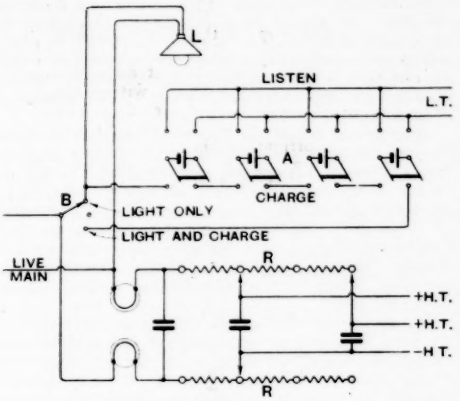


Fig. 1.

A. 4 *D.P.D.T. switches with* 1 *D.T.G. cell across each pair of centre terminals.*
B. *Room switch with* 1 "*off*" *and* 2 "*on*" *positions.*
R. *Tapped non-metallic resistances.*
L. *Room lamp,* 60*-watt* $= \frac{60}{1,000} \times 4 = \frac{1}{4}$ *amp.*

Capacity 1 *hour listening at* 1 *amp per* 1 *hour light. Total cell capacity,* 40 *amp hour actual.*

Secondly, it is always easier to get silence where the negative main is the live one, possibly because of the capacity of the receiver as a whole, but mainly because of the sensitiveness of the phones or speaker to commutator hum independently of the receiver altogether.

This is alluded to by Mr. Robertson.

Where the + main is earthed this purely magnetic pick up is, of course, absent, and we have the option of connecting the H.T. + to earth, or to the neutral main.

Practically it always proves best to connect the L.T. + back to neutral and the H.T. + to earth.

Thirdly, it is easier to get rid of a true alternating hum than of commutator noises, for one thing the voltage drop available is greater on A.C. supplies and for another the sparking of D.C. machines is absent or smoothed out in the transformers.

Fourthly, if chokes and condensers are used, two chokes and two condensers are enormously more efficient than one of each of the same total values. But a resistance is always more effective than a choke (except in the case of A.C. where the choke works in an entirely different way).

Fifthly, it is better to use a non-metallic than a metallic resistance or choke; for instance, the neon lamp is far more efficient than a combination of lamps of the same resistance, and it is better to get lower voltages by tapping the highest voltage through a resistance, than to use a potentiometer. The L.F. end is far less sensitive to hum than the detector (which requires the least voltage), and by drawing off and further smoothing the highest H.T. supply we both gain efficiency and save expense.

The writer finds that any non-metallic resistance in the form of a pencil is better than a wire wound resistance.

The writer cannot agree that the condensers across the H.T. + and H.T.— take no part in the smoothing.

The use of twelve lamps in series is of course not commercially practicable, and is in any case unduly expensive and easily replaceable by one or two lamps and a series resistance tapped for the different voltages.

Another point here is that no supply company will allow lamps to be used as resistances on the low rate of one penny per unit.

As regards running valves in parallel, in series with resistances, it would be cheaper to put in a D.T.G. as a floating battery than to risk burning out a 16s. valve.

Sixthly, there is no advantage in the use of a potentiometer drawing, say, 0.1 amp from the mains (all of which has to be smoothed) instead of the .02 given by a neon lamp and a condenser with a series resistance for varying the voltage, except that it enables the valves to be lit (somewhat riskily) off the mains.

Seventhly, it is a better proposition to keep the L.T. off the mains entirely and to use the room light for charging the batteries in *series* and to use them on the receiver in *parallel.*

I give herewith a diagram showing the connections of a complete unit of the most economical type, using 4 D.T.G. cells costing less than one accumulator of equivalent total size.

In conclusion, this unit costs nothing to run, the cells are always fully charged and only require topping every six months, and the whole cost of the installation if made at home will not exceed £2 10s., including cells, switches, lamps and sundries. By having four positive and four negative tappings we can vary the positives separately, or as a whole by moving the negative.

The unit is perfectly safe as there are lamps on both mains supplies, and even on a 250-volt main with the negative adjusted to ±120 volts, this is the maximum shock that can be taken from the unit.

Luton. ERNEST J. BATY.

Directory of Sources of Special Information.

To the Editor, E.W & W.E.

SIR,—Just as the practical utility of a book is impaired by the want of an index, so the vast aggregation of knowledge that has been built up and is in many cases being added to day by day is largely lost to mankind owing to the lack of a master-key to its whereabouts. Throughout this country there are numerous centres of specialised knowledge and experience of the most varied description, the existence of which has only to be known for them to prove of great service to the world.

It is with the object of bringing these to light and recording their salient features in concise form that the Association of Special Libraries and Information Bureaux, in collaboration with the Carnegie United Kingdom Trust, has asked me to compile a Directory.

It has been decided to go forward with the printing of a first edition of this Directory at midsummer, but much still remains to be done. It is recognised that completion in any one subject is well-nigh impossible in so short a time. It would, however, greatly further this end if libraries, organisations, firms and individuals possessing special information on any subject and willing to answer inquiries thereon, which have not yet been in touch with us would communicate with me at 38, Bloomsbury Square, W.C.1.

Yours faithfully,

(Signed) G. F. BARWICK, General Editor,
late Keeper of Printed Books,
British Museum.

A New Development in Resistance Amplification.

To the Editor, E.W. & W.E.

SIR,—Mr. Colebrook's article on "Resistance Amplification" in your April issue is most timely, in view of the large amount of attention which the use of extra high anode resistance is receiving, and the widespread misunderstanding of the conditions required for the best results. He has provided clear theoretical and practical data in place of the rather hazy ideas which have been current, and in particular has dealt with the limitations inherent to the method, which have not been clearly set forth hitherto.

There is, however, an aspect of the matter which is of considerable practical importance, and concerning which no information has, as far as I am aware, been published. From the nature of the method, which is applicable only to relatively small input voltages, it follows that the most logical arrangement is to use the high anode resistance to couple the detector to the succeeding valve (and possibly in the next stage also). Now, as Mr. Colebrook has done such valuable work on detector efficiency, it would be particularly interesting to have some correlation of the two subjects; in other words, what conditions must be applied in order to obtain the best overall amplification, taking into account the effect of the resistance on efficiency of rectification?

Again, one must consider the rejection of radio frequencies from the audio stages. This is of great importance in supersonic receivers, but is by no means to be neglected in "straight" sets. The simplest method is to use a condenser of the order of 1,000$\mu\mu$F across the coupling, but, as Mr. Colebrook shows, the capacity here should not greatly exceed that due to the interelectrode capacity, when the anode resistance is of the order of megohms.

By using the more elaborate types of filter the problem is partly solved, but only by adding considerably to the complication of the amplifier. It would appear, therefore, that the use of high anode resistance is subject to greater limitations in the detector stage than in a true audio stage, in cases where the radio frequency is low or the total magnification very high; for the straying of radio frequency currents beyond their proper bounds is one of the most fruitful causes of trouble in such receivers.

MARCUS G. SCROGGIE, B.Sc.

ERRATUM.

"The Horizontal Hertzian Aerial for Transmission," page 145, numbering of Figs. 2 and 3 should be transposed.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

ÜBER DIE BESTIMMUNG DES NEIGUNGSWINKELS ELEKTRISCHER WELLEN UND DIE AUSSCHALTUNG GENEIGT EINFALLENDER WELLEN AM EMPFÄNGER (On the determination of the angle of inclination of electrical waves and the exclusion of inclined incident waves from the receiver).—A. Esau. (*Zeitschr. f. Hochfrequenz.*, 29, January, 1927, pp. 4-10.)

In an earlier paper (*Zeitschr. f. Hochfrequenz.*, 28, August, 1926, pp. 50-53; these abstracts, *E.W. & W.E.*, December, 1926, p. 766), it was shown that the fading phenomena due to changes of polarisation of electric waves can be eliminated by coupling a vertical and a horizontal antenna of suitable form to a common circuit tuned to the incoming wave. The present article deals with the problem of getting rid of the fading caused by inclined waves of differing phase difference entering the receiver. If these rays interfere with one another or with the direct ray arriving at the receiver, the intensity received can alter up to complete extinction, or in telephony, the speech or music conveyed can be distorted. This latter effect has been pointed out by Bown, Martin and Potter (*Proc. Inst. Radio Eng.*, 11, 1926, p. 106).

The solution of the problem consists in securing that the indirect ray when it arrives at the receiver will have no action upon it, the direct ray alone being able to bring the receiver to respond. An ideal solution in which *complete extinction* of all inclined incident rays occurs is not to be found, as this paper shows. By a right choice of the receiving system and angle of inclination, however, a more or less marked attenuation can be attained, which should suffice in the majority of cases to prevent complete vanishing of the intensity and considerably diminish distortion, due to interference.

It is shown in the second part of the article that combinations of vertical undirectional antennæ are most suitable for separating out inclined incident waves at the receiver, their distance apart being chosen so that the ratio d/λ is smaller than about 1/10. The greater the number of antennæ the less will the receiving system they form respond to inclined waves.

In the first part of the article, three possible receiving arrangements employing a vertical and horizontal antenna are found for determining the angle of inclination of an incident wave, namely, vertical frame and straight horizontal wire, vertical and horizontal frames, vertical and horizontal wires; there resulting from the measurement of the currents in both antennæ, the sine, tangent or cotangent respectively of the angle of inclination, according to the arrangement used. A straight vertical wire and horizontal frame will not do, this arrangement yielding instead of the angle of inclination, the angle of rotation of the plane of polarisation, as described in the paper referred to at the outset.

INCLINAISON DES ONDES ET SYSTÈMES DIRIGÉS (Inclination of waves and directional systems).—L. Bouthillon. (*Comptes Rendus*, 184, 24th January, 1927, pp. 190-192.)

As a result of experiments with radio waves of 10-50 metres, it is generally admitted that the rays that are most useful at a great distance are those leaving the transmitter at a relatively small angle with the zenith, some 20° at the most. It also seems to be proved experimentally that antenna systems erected with a view to concentrating the waves in a given direction are much less effective at a great distance than theory would predict. In particular, mention is made of the projector recently set in operation by the Marconi Company at Bodmin, which was expected to radiate practically in a single direction, but is also vigorously received in the opposite direction. In this paper a relation between these two results is established, explaining how it is that in proportion as the useful rays approach the zenith, directional transmitting systems become less and less efficacious from the viewpoint of wave concentration.

The results are given here for the case of the Marconi projector (curtain antenna with parallel reflector), showing that for the Bodmin antenna,

$$\frac{d}{\lambda} = 14.6, \quad \frac{d'}{\lambda} = \frac{1}{4},$$

d being the width of the curtain and d' the distance between curtain and reflector.

With the rays horizontal, there is a very narrow principal beam orientated perpendicularly to the curtain in the direction from reflector to curtain, and adjacent beams of very reduced intensity: in the direction opposite the special direction the radiation is nil. As the rays depart from the horizontal and approach the zenith, the principal beam becomes weaker and broader, while the adjacent beams assume more importance, and in the opposite direction to the principal one, a beam of increasing intensity appears, becoming comparable with the principal beam: when the rays become quite vertical, the system is not directional at all.

Inserting numerical values for different angles, the table below shows:—

1. The ratio of the amplitude in the special and in the opposite direction.

2. The aperture of the principal beam.

Angle with the vertical =	90°	30°	14° 30′	7° 11′	0°
Amplitude in the direction opposite the special one / Amplitude in the special direction =	0	0·42	0·73	0·82	1
Aperture of the principal beam =	7° 50′	15° 44′	31° 46′	66° 20′	360°

ON THE WIRELESS BEAM OF SHORT ELECTRIC WAVES (IV).—S. Uda. (*Journ. Inst. Elect. Engineers of Japan*, No. 462, January, 1927, pp. 26-51.)

The action of a straight metal rod of finite length, erected vertically in the radiation field of a transmitting antenna, is investigated theoretically and tested by experiment; the results are as follows:—

When the natural frequency of this metal rod is equal to the wave frequency, the current induced in it will be in phase with the E.M.F. caused by the wave, and the wave is reflected by the rod. Even if the natural frequency is made somewhat lower than the resonance frequency by increasing the length of the rod, the current induced in it will be lagging behind the E.M.F. and the reflecting action will still be manifest. If, however, the natural frequency is made somewhat higher than the resonance frequency by shortening the rod, the induced current will be leading the E.M.F., and when the phase angle and magnitude of the current reach suitable values, the wave is transferred further forwards beyond the rod. The rod is now acting as a means of converging the wave energy and transmitting it further with more concentration and is therefore now called a wave director.

ON THE WIRELESS BEAM OF SHORT ELECTRIC WAVES (V) (High angle radiation of short-wave beam).—S. Uda. (*Journ. Inst. Elect. Engineers of Japan*, No. 462, January, 1927, pp. 52-62.)

Description of an experimental investigation of the distribution of energy in a vertical plane radiated from a transmitting antenna tuned in different higher harmonics.

The field intensities in various altitudinal directions are measured by the receiving apparatus which is moved along a vertical line. A single vertical metal rod is used as antenna and at first is not earthed. The length of the antenna is varied so that it equals λ, $\frac{3}{2}\lambda$, or 2λ ($\lambda = 266$ cms.) and oscillates in the second, third, or fourth harmonic. Distribution diagrams for these cases are given and curves plotted. The following conclusions are confirmed:—

The wave energy is projected chiefly upwards, practically no radiation being transmitted along the earth's surface. When the length of the antenna exactly equals a wavelength, only one maximum radiation will occur, but when it equals $\frac{3}{2}\lambda$ or 2λ, the wave directed upwards will split into two or three parts and consequently there will be two or three points of maximum radiation.

Experiments were also made with the earthed vertical antenna of length $\frac{3}{4}\lambda$, $\frac{5}{4}\lambda$, $\frac{7}{4}y$, or $\frac{9}{4}\lambda$. In these cases again the radiation projected at high angles is very intense while the energy flowing along the earth is very feeble, also in the two latter cases, when the antenna is excited in the 7th or 9th harmonic, the wave radiated upwards will split into two or three parts.

It is further shown that directional transmission with high angle radiation is readily obtained by using three vertical metal rods making up the trigonal reflecting system. Here the antenna and the three reflectors are made equal to the wavelength and thus they are all excited by the second harmonic oscillation. The distribution curves clearly show that these three reflectors are effective in producing a directional radio wave with high angle radiation. If, in addition to the trigonal reflector, several wave director rods arranged along an inclined line of the direction of maximum radiation are employed, the directivity will be much improved.

SHORT WAVE WIRELESS TELEGRAPHY.—T. Eckersley. (*E.W. & W.E.*, April, 1927, pp. 213-222.)

Abstract of a Paper read before the Wireless Section, I.E.E., 2nd March, 1927.

The paper deals with short-wave practice and theory, the discussion falling into four sections: 1. The aerial transmission characteristics, in particular the computation of vertical polar diagrams; 2. Results of experiments with short-wave direction finding; 3. Results of a series of long-distance transmission tests, on waves between 25 and 10 metres; 4. General theory of ionic refraction, etc.

DISCUSSION ON LONG DISTANCE RADIO RECEIVING MEASUREMENTS AT THE BUREAU OF STANDARDS IN 1925 (L. W. Austin).—K. Sreenivasan. (*Proc. Inst. Radio Engineers*, 15, February, 1927, pp. 155-157.)

It is pointed out that while the Washington observations (monthly averages) on Bordeaux always show an increase in field strength, the curves obtained by Hollingworth (weekly averages) sometimes show as marked a reduction in field intensity. The writer inclines to doubt the increase in every case.

It is agreed that the slight but regular increase in yearly average intensity generally found is probably due to changes in the Kennelly-Heaviside layer, either in average height or in ionisation, possibly connected with changes in solar activity.

MAGNETIC STORMS AND WIRELESS TRANSMISSION.—E. V. Appleton. (*Electrician*, 98, 11th March, 1927, pp. 256-257.)

The existence of a conducting layer in the upper atmosphere has been postulated in the study of terrestrial magnetism to explain its diurnal variations. Such a layer has also been assumed by the radio investigator to account for the facts of wireless transmission. Until recently, however, the evidence presented by the two subjects has contained two important discrepancies: one, that terrestrial magnetism demanded a higher layer conductivity than wireless telegraphy, and the other, the absence of obvious correlation between magnetic and wireless irregularities.

In this article the author shows how these discrepancies have been removed by recent experimental results, and gives a revised interpretation of the data.

THE SUN, THE EARTH'S ATMOSPHERE, AND RADIO TRANSMISSION.—S. Chapman. (*Nature*, 19th March, 1927, pp. 428-429.)

The presence of ions in the upper atmosphere is now known to be of the greatest importance for

radio communication—refracting the waves, absorbing their energy, and, in conjunction with the earth's magnetic field, changing their polarisation. It has been suggested that the source of this ionisation is the penetrating radiation studied by Kolhörster, Hess and Millikan, or the runaway electrons whose probable occurrence during thunderstorms has been pointed out by C. T. R. Wilson, but the author here shows that it is unlikely that the ionisation thus produced compares at all in importance with that due to the sun. He discusses in detail the action of the two independent solar ionising agents: ultra-violet radiation, travelling rectilinearly and reaching only the sunlit hemisphere; and a corpuscular radiation coming from locally disturbed areas on the sun's surface, falling not only on the day side but also bent round to the night side of the earth.

THE CORRELATION OF RADIO RECEPTION WITH SOLAR ACTIVITY AND TERRESTRIAL MAGNETISM. — G. Pickard. (*Proc. Inst. Radio Engineers*, 15, February, 1927, pp. 83-97.)

A full account of the correlation between radio reception, solar activity and magnetic disturbances is not yet possible, owing to insufficient data, and this paper is just a progress report setting forth the results so far obtained and emphasising the importance of systematic long-period observations of radio reception. Various series of observations are tabulated and shown graphically.

THE ABSORPTION OF RADIO WAVES IN THE UPPER ATMOSPHERE.—E. Hulburt. (*Physical Review*, 29, 2, February, 1927, p. 365.)

Abstract of a Paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

The absorption of radio waves in the upper atmosphere, put on one side in the theory of Taylor and Hulburt because of its smallness, has been calculated on the assumption that it results from collisions between the electrons and molecules of the atmosphere. Formulæ are derived for the dispersion and absorption of the variously polarised waves, and quantitative agreement is indicated with observed data of ranges and degradation of intensity with distance from the transmitter.

ATMOSPHERIC ELECTRICITY.

THE ELECTRIC FIELDS OF SOUTH AFRICAN THUNDERSTORMS.—B. Schonland and J. Craib. (*Proc. Royal Society*, 114A, March, 1927, pp. 229-243.)

Evidence of the bipolar nature of thunderclouds is presented, and the strong predominance amongst such clouds of a type in which the upper pole is positive and the lower pole negative. This preponderance of the positive type suggests that Dr. Simpson's theory of the production of the charge by the breaking up of large water-drops in an ascending air current, which would produce a cloud of negative polarity, must either be rejected or radically altered. On the other hand, this positive polarity of thunderclouds is required by Prof. C. T. R. Wilson's theory for the replenishment of the negative charge on the surface of the earth, the ionisation currents between the bases of these clouds and the ground serving to maintain the earth's charge at a steady value in spite of the reverse current flowing in regions of fine weather.

ATMOSPHERIC ELECTRICITY.—L. Bauer. (*Nature*, 26th March, 1927, p. 457.)

Some remarks on Dr. Chree's letter in *Nature* of 18th December, 1926, followed by a reply from Dr. Chree.

COSMIC ASPECTS OF ATMOSPHERIC ELECTRICITY.—L. Bauer. (*Physical Review*, 29, February, 1927, p. 371.)

Abstract of a Paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

There being at present no generally accepted theory to account for the origin and maintenance of the earth's negative electric charge, it is of peculiar interest to study the laws and *modus operandi* of the changes to which atmospheric electricity is subject during the day, year, and from year to year. These changes, which even on meteorologically-undisturbed days are of the order of the absolute values of the atmospheric elements themselves, show remarkable terrestrial and cosmical aspects, *i.e.*, they are in general of the same character and sign at stations both in the northern and southern hemispheres. Recent world-wide observations give further confirmation of these striking facts. A brief discussion is also given of the relation of the atmospheric-electric results to recent measurements of the ozone content of the atmosphere, of the sun's ultra-violet radiation, of radio-reception, and of solar activity.

ON THE EFFECTS OF DUST, SMOKE, AND RELATIVE HUMIDITY UPON THE POTENTIAL GRADIENT AND THE POSITIVE AND NEGATIVE CONDUCTIVITIES OF THE ATMOSPHERE.—G. Wait. (*Physical Review*, 29, February, 1927, p. 372.)

Abstract of a Paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

Simultaneous observations of atmospheric electricity, dust-content, and relative humidity, obtained at the Watheroo Magnetic Observatory, Western Australia, are discussed.

The dust-content series indicate that the potential gradient is approximately doubled for increase of dust-content from zero to 10,000 particles per c.c., and thereafter a very slow increase with increased dust-content. Both positive and negative conductivities decrease about half when the dust-content changes from zero to about 5,000 particles per c.c. and decrease very slowly thereafter with increased dust-content. The ratio of positive to negative conductivity increases with increasing dustiness. The importance of more observations on the behaviour of ions in air is pointed out.

TRANSMISSION.

SOME NOTES ON DESIGN DETAILS OF A HIGH-POWER RADIO-TELEGRAPHIC TRANSMITTER USING THERMIONIC VALVES.—R. Hansford and H. Faulkner. (*Journ. Inst. Electrical Engineers*, 65, March, 1927, pp. 297-326.)

Paper read before the Wireless Section, 1st December, 1926, dealing with certain specific details of design and operation of the Rugby valve transmitter, consisting of the following more or less independent sections :—

1. Consideration of the most suitable type of aerial circuit, from the point of view of the elimination of undesirable harmonic emissions.
2. The design of the electrical proportions of the aerial circuit.
3. The inductance coils for the aerial circuit.
4. Some notes on valve circuit design.
5. Keying and shape of signals.
6. Recent results at Rugby.

SOME EQUIPMENT USED IN TRANSATLANTIC RADIO TELEPHONY.—(*Electrical World*, 26th February, 1927, p. 442.)

Illustrations are shown of the circular bank of 15 water-cooled power amplifier valves at Rocky Point, also an intermediate amplifier group for raising the level of the voice currents from an initial 50 watts to 15kW, and the high-voltage rectifier with 12 diodes each rated at 20kW with a plate current of about 2 amps and a filament current of 41 amps supplied by 22 volts, alternating current.

INTERMITTENT VALVE OSCILLATOR.—L. Taylor. (*Journ. Franklin Institute*, 203, March, 1927, pp. 351-374.)

Account of an investigation of an oscillating circuit maintained by a thermionic valve which oscillates only during certain definite intervals of time, the effect being procured by inserting suitable high resistance and capacitance in the grid circuit.

SPACE CHARACTERISTICS OF ANTENNÆ. — W. Murphy. (*Journ. Franklin Institute*, 203, February, 1927, pp. 289-311.)

The first article on this subject was published in the *Franklin Institute Journal* of April, 1926 (these abstracts, *E.W. & W.E.*, June, 1926, p. 382). The present article deals with the reception characteristics of antennæ ; the application of the previously obtained electrostatic field equations to receiving antennæ, by which means induced voltage equations are evolved ; the directional effects obtained between airplanes and ground stations as well as between airplanes in parallel flight ; and the bearing errors met with when using loop or horizontal antennæ. It is shown that the transmission and reception characteristics of a given antenna are equal and that the induced voltage characteristics obtained for two antennæ are the same regardless of which is transmitting. In conclusion, the effect of antenna combinations in which current and space phase displacements are taken into account are discussed, and equations including the phase displacement angles evolved.

ZUR THEORIE DER EXTREMEN SCHNELLTELEGRAPHIE (On the theory of extremely high-speed telegraphy).—W. Ludenia. (*Elecht. Nachr. Technik*, 4, 2, 1927, pp. 93-96.)

A mathematical analysis of the damping relations in high-speed transmitting and receiving circuits and the process of multiple telegraphy on one wave.

RECEPTION.

EIN BEITRAG ZUR THEORIE DER NIEDERFREQUENZ-VERSTÄRKUNG MIT WIDERSTANDSKOPPLUNG (A contribution to the theory of low-frequency amplification with resistance coupling).—H. Kafka. (*Zeitschr. f. Hochfrequenz.*, 29, February, 1927, pp. 39-45.)

The object of this paper is to represent the frequency dependence of a low-frequency stage with resistance coupling by means of a locus diagram. With this very clear form of representation, the influence of the different factors that come in, on the amplification and its dependence upon frequency, can be seen much more readily than from formulæ. The first step in the solution of the problem is to obtain the fundamental valve equations, and an expression is found in which the tension relation E_{g_2}/E_{g_1} is represented by a plane vector, whose value and direction change with the frequency. To represent plane vectors graphically, a rectangular system of coordinates is employed with origin o, whose vertical axis is called the effective axis ω, and horizontal axis the blind axis b. The figure expressing the dependence upon frequency constitutes an objective base for investigating whether this or that resistance combination is the more suitable for a given case, and the relations developed provide starting-points for calculating the circuits. In order to approach as near the actual conditions as possible, the valve capacities and load conditions of the next stage are taken into account.

A NEW DEVELOPMENT IN RESISTANCE AMPLIFICATION. — F. Colebrook. (*E.W. & W.E.*, April, 1927, pp. 195-205.)

A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF DETECTION FOR SMALL SIGNALS.—E. Chaffee and G. Browning. (*Proc. Inst. Radio Engineers*, 15, February, 1927, pp. 113-153.)

The paper presents the theory of detection for both two and three-electrode devices, expressed in terms of the circuit impedances and the first and second partial differential coefficients of the static characteristic curves of the device, taken at the points on the characteristic curves determined by the steady polarising voltages. It is then assumed that the impressed signal is so small that for any given steady voltages these coefficients can be supposed constant within the range of the variations due to the signal voltage. A small signal voltage is defined as one less than 0.05 volt r.m.s.

BOUCHEROT'S CONSTANT-CURRENT NETWORKS AND THEIR RELATION TO ELECTRIC WAVE FILTERS —A. Bartlett. (*Journ. Inst. Elect. Engineers*, 65, March, 1927, pp. 373-376.)

The circuit arrangements devised by Boucherot to give a constant-current supply from a constant-voltage supply are briefly described, and it is shown that they may be regarded as simple examples of a more general property of all electric filters.

RADIO TELEGRAPH RECORDER.—A. Jipp. (*Siemens Zeitschrift*, December, 1926.)

A German firm has developed a mechanical Morse recorder, similar to the siphon recorder of trans-oceanic telegraphy, which not only secures reception up to 2,000 letters a minute, but is practically unaffected by atmospheric interference. The instrument is essentially a moving-coil galvanometer, the coil being suspended between two short lengths of steel wire: at the end of the horizontal writing lever, a fine silver tube is fastened, one end of which touches the recording tape, while the other moves in a drop of recording ink maintained by a simple feeding mechanism.

EIN NEUES RELAIS FUR EXTREM SCHWACHE STRÖME (A new relay for extremely weak currents).—H. Richter and H. Gaffcken. (*Zeitschr. f. Techn. Physik*, 7, 12, pp. 601-606.)

There is a description of this very sensitive glow-discharge relay in *Wireless World* of 2nd March, 1927, p. 262.

LOUD-SPEAKER DIAPHRAGMS. — N. McLachlan. (*Wireless World*, 23rd April, 1927, pp. 345-350.)

The problem of the vibrating disc is considered, and the influence of diameter on interference effects at high frequencies.

LA SOUPAPE ELECTROLYTIQUE (Electrolytic valve). —Y. Doucet. (*Q.S.T. Français et Radio Electricité Réunis*, March, 1927, pp. 14-18.)

Account of the determination of the conditions of optimum efficiency.

HIGH PRESSURE POWDER CONTACT RECTIFIER.—J. Lilienfeld and C. Thomas. (*Physical Review*, 29, 2, February, 1927, p. 367.)

Account of a rectifier making use of the known contact combination, aluminium to cupric sulphide. The pressure is of importance with regard to the rectification, and a compression force of about one thousand pounds is supplied by a helical spring. Oscillograms of the current through a resistance load show complete and distortionless full wave rectification, while those of the current through a new filter circuit of inductances and resistances show suppression of the ripple to less than 1 per cent. of the total voltage.

THE RESULTANT CAPACITY OF AERIAL SYSTEMS EMPLOYING SERIES TUNING CONDENSERS.—W. Griffiths. (*E.W. & W.E.*, April, 1927, pp. 206-212.)

VALVES AND THERMIONICS.

THE INPUT IMPEDANCES OF THERMIONIC VALVES AT LOW FREQUENCIES. — L. Hartshorn. (*Proc. Physical Society*, 39, 15th February, 1927, pp. 108-123.)

It is shown that accurate measurements of input admittance (or of input impedance) under various conditions can be made by means of the Schering Capacity Bridge. The input circuit is regarded as being equivalent to a condenser with a definite phase angle, ϕ, or "loss angle," $\delta = 90° - \phi$, and the results are expressed by stating the effective capacity and value of $\tan \delta$ for each set of experimental conditions.

A series of experiments made on an *R* valve is recorded, and it is shown that the results are in good agreement with the theoretical investigations of Miller and Nichols. The theoretical investigation has been extended to allow for the effect of dielectric losses in the valve, since these were found by experiment to be rather large, and to have an appreciable effect on the capacity and phase angle of the input circuit.

It is shown that the effective capacity may vary from about 10$\mu\mu$F to 100$\mu\mu$F for an R valve, and the phase angle may vary from about 80° leading to 126° leading, depending mainly on the load in the anode circuit. Values of phase angle greater than 90° correspond to a negative resistance, or negative power factor, and occur when the load in the anode circuit is inductive. The variations of input capacity and phase angle with filament voltage, anode voltage, input voltage, and frequency are also investigated.

TEMPERATURE DISTRIBUTION ALONG A FILAMENT.—V. Bush and K. Gould. (*Physical Review*, 29, February, 1927, pp. 337-345.)

A method has been developed for adapting a new integrating machine to the solution of:—

1. The integral equation which applies to the distribution of thermionic emission along the central portion of a long filament in an evacuated vessel, the effect of the thermionic emission upon the filament temperature being considered.
2. The differential equation which applies to the temperature distribution near the end of a long filament from which the thermionic emission is negligible compared with the filament heating current.
3. The integro-differential equation which applies to the distribution of temperature and thermionic emission along an entire filament heated in an evacuated vessel by a direct current. This takes into account the effects of thermionic emission as well as cooling due to thermal conduction.

All these solutions fully account for the variation of the following quantities with temperature, graphical relations being used throughout: (*a*) thermal conductivity, (*b*) thermionic emission, (*c*) resistivity, (*d*) radiation. The method has been applied to various typical cases of tungsten and thoriated tungsten filaments, and in those cases where an experimental check was possible it was found that the results were in good agreement with the measured quantities.

THERMIONIC VALVE MANUFACTURE.—G. Paterson. (*Electrician*, 98, 11th March, 1927, pp. 262-263.)

Abstract of a paper read at the Royal Society of Arts on 16th February, 1927.

MICROPHONIC NOISES.—P. Tyers. (*Wireless World*, 9th March, 1927, pp. 304-305.)

A note on the mounting of valves.

ÜBER DEN ELEKTRONENAUSTRITT AUS METALLEN UNTER WIRKUNG HOHER FELDSTÄRKEN (On electronic emission from metals under the influence of high field intensities.). — G. Hoffmann. (*Ann. d. Phys.*, 82, 2, 1927, pp. 254-256.)

Some remarks on Rother's paper (*Ann. d. Phys.*, 81, 1926, p. 317).

INTERPRETATION OF DATA DEALING WITH THERMIONIC EMISSION.—W. Ham. (*Physical Review*, 29, 2, February, 1927, p. 364.)

Abstract of a Paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

PHENOMENON OF DIRECT-CURRENT SELF-EXCITATION IN VACUUM TUBE CIRCUITS AND ITS APPLICATIONS.—N. Minorsky. (*Journ. Franklin Institute*, 203, February, 1927, pp. 181-209.)

Theoretically the application of valves in direct-current circuits is very attractive, but the difficulties inherent in existing schemes of D.C. amplification are considerable. The purpose of the present investigation is to eliminate some of these difficulties, particularly the necessity of using very large grid batteries specially difficult to adjust when several stages of amplification are used. Incidentally, it was discovered that under certain conditions the valve system acquires entirely new properties compared with those of an ordinary amplifier; namely, its performance can become abrupt, similar to the action of an ordinary contact, which lends itself to important applications.

MEASUREMENTS AND STANDARDS.

PRECISE DETERMINATION OF FREQUENCY BY MEANS OF PIEZO-ELECTRIC OSCILLATORS.—J. Tykocinski-Tykociner. (*Physical Review*, 29, 2, February, 1927, p. 366.)

Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

The oscillating current whose frequency is to be determined is inductively superimposed upon the oscillations of a piezo-electric oscillator. The plate current of the driving thermionic oscillating valve is compensated by a potentiometer arrangement so that the current variations can be observed by a microammeter. The relation between the plate current of the piezo-electric oscillator and the exciting frequency was investigated experimentally. The curves show a sharp current maximum and minimum with an intermediate steep line crossing the zero current abscissa. The point of intersection corresponds to resonance. If the exciting frequency exactly equals the fundamental frequency or a harmonic of the piezo-electric oscillator, no influence whatever is exerted on the plate current; but a deviation of 1.15 of the frequency measured can still be detected when the quartz crystal is clamped between two electrodes; with the crystal free, frequency variations less than one in a million are detected by a violent vibration of the microammeter pointer. The plate current variation in the measured circuit is of a different character and less pronounced.

FACTORS AFFECTING THE CONSTANCY OF QUARTZ PIEZO-ELECTRIC OSCILLATORS.—E. Terry. (*Physical Review*, 29, 2, February, 1927, p. 366.)

Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

A study is made of the effect of mechanical stresses, temperature, and circuit constants upon the frequency of an oscillating plate of quartz connected in the usual way across the grid-filament elements of a valve, a tuned resonance circuit being placed in series with the plate. Frequency changes were measured by determining the change in pitch of the audio-frequency beat note between this oscillator and a similar one furnishing a constant frequency. Various kinds of deformation were produced by loading the plate at different places and also by subjecting it to different air pressures.

IMPORTANCE OF LABORATORY MEASUREMENTS IN THE DESIGN OF RADIO RECEIVERS.—W. MacDonald. (*Proc. Inst. Radio Engineers*, 15, February, 1927, pp. 99-111.)

The thirteen fundamental measurements of a receiver are given as follows:—

1. Voltage step-up of input coupling transformer.
2. Voltage step-up of 1st valve and coupling transformer.
3. Voltage step-up of 2nd valve and coupling transformer.
4. Voltage step-up of following stages.
5. Complete R.F. amplification from input coupling-coil to the detector.
6. Resonance characteristic of input coupling transformer.
7. Resonance characteristic of 1st stage transformer.
8. Resonance characteristic of 2nd stage transformer.
9. Resonance characteristic of following stage transformers.
10. Resonance characteristic of complete R.F. amplifier from input to the detector.
11. Amplification and frequency characteristics of 1st audio transformer.
12. Amplification and frequency characteristics of other audio transformers.
13. Relative frequency characteristics of complete audio system including detector.

The apparatus required is described and the manner in which the experiments are carried out.

A new Loss-measuring Device and its Application to High-Frequency Measurements. —P. Cooper. (*Philosophical Magazine*, 3, March, 1927, pp. 625-638.)

Description of a method employing a fixed resistance in series with a variable condenser. The fixed resistance consists of a single straight wire of the smallest available gauge, and the change in frequency accompanying the use of a variable condenser in series with this resistance is compensated by a second condenser.

Eine Methode zur Bestimmung extrem hoher Widerstände und Kapazitäten mittels Kippschwingungen (A method for determining extremely high resistances and capacities by means of tilting oscillations).—E. Kurz. (*Archiv. f. Elektrotechnik*, 17, 4, pp. 413-415.)

Appareil à Lecture Directe pour la Mesure des Champs Magnétiques—Gaussmètre (Direct-reading instrument for measuring magnetic fields. A gaussmeter).—G. Dupouy (*Comptes Rendus*, 184, 14th February, 1927, pp. 375-377.)

A crystal of iron carbonate is mounted so that it can move about a suitably chosen axis. When it is placed in a uniform magnetic field, it is subjected to a couple proportional to the square of the field tending to orientate it. This couple is balanced by an opposing couple due to the torsion of a thread or spiral spring attached to a pointer moving over a graduated scale. For every value of the field there is a certain position of equilibrium which can be read off on the dial.

Measurement of Earthing Resistances. (*Electrician*, 18th March, 1927, pp. 288-289.)

Technique of the Dufour Cathode Ray Oscillograph for the Study of Short Time Occurrences. — G. Harrington and A. Opsahl. (*Physical Review*, 29, 2, February, 1927, p. 364.)

Abstract of paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

Methods, circuits and procedure are set forth for using the Dufour plate-in-vacuum cathode ray oscillograph for the investigation of phenomena of such short time duration as to preclude the effective use of any other known oscillograph.

A Multi-Range Absorption Circuit.—A. Castellain. (*Wireless World*, 23rd March, 1927, p. 357.)

Description of a simple method of checking wavemeter calibration.

GENERAL PHYSICAL ARTICLES.

Sub-fundamental piezo-electric Vibrations in Quartz Plates. —J. Harrison. (*Physical Review*, 29, 2, February, 1927, p. 366.)

Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

With a new type of piezo-electric crystal mounting, it has been found possible to obtain piezo-electric reactions of very much lower frequency than that of the transverse fundamental, first described by Cady. The "transverse fundamental" is the frequency of the compressional wave in the direction of the largest dimension of the plate, both ends being free. The new mode of vibration is also different from any previously observed in that it is dependent to a large degree on more than one crystal dimension. The crystal mounting is so designed that the electric field is applied to two areas which are symmetrically disposed with respect to the longitudinal axis of the quartz plate, and the polarities in the quartz are in opposite directions. With the electric field applied in this manner, piezo-electric crystals operate successfully either as resonators or as oscillators at this subfundamental frequency. The luminous glow emitted by crystals when resonating in a low pressure chamber, lately described by Giebe and Scheibe (*E.T.Z.* 13, 380), can also be observed at the subfundamental frequency, the luminosity presenting striking peculiarities which still await explanation.

Über piezo-electrische Kristalle bei Hochfrequenz, II (On piezo-electric crystals at high frequency, II.—A. Meissner (*Zeitschr. f. techn. Physik*, 8, 2, 1927, pp. 74-77.)

The relation between optical and mechanical directions of rotation and piezo-electric charge is discussed. A structural model of quartz is given, and the difference between α and β quartz shown. Piezo-electricity is explained by the pressure and tension applied displacing the atomic charges of a structural element from their position of equilibrium, thus producing the piezo-electric charges. Pyro-electricity is explained by an unequal displacement of the silicon and oxygen atoms from the position of equilibrium with rise or fall of temperature. From the model it is seen that the rotation of the plane of polarisation of light is effected probably through the silicon atoms alone.

Spectrographic Observations of the Second Green Line of the Auroral Spectrum.—L. Vegard. (*Nature*, 119, 5th March, 1927, p. 349.)

A spectrogram obtained for the second green line is shown, which the author states confirms his view with regard to the origin of the auroral spectrum. It is concluded that what is called the second green line is not a single line, but consists of a group of lines, which is also the case with the N_2 line from solid nitrogen.

Propagation of Electromagnetic Waves along Co-axial Cylindrical Conductors separated by two Dielectrics.—N. Frank. (*Physical Review*, 29, 2, February, 1927, p. 365.)

Abstract of a Paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

A solution of Maxwell's equations for the cable problem.

ÜBER DIE MESSUNG DER GESCHWINDIGKEITS-AMPLITUDE UND DER DRUCKAMPLITUDE IN SCHALLFELDERN (On the measurement of the velocity and pressure amplitude in sound fields.—E. Meyer. (*Elect. Nachr. Technik*, 4, 2, 1927, pp. 86-90.)

For the velocity measurement the Rayleigh disc is employed, and for the pressure measurement a condenser-microphone in a new compensating circuit-arrangement. Comparison measurements carried out in open sound fields yielded satisfactory agreement.

THE DIRECT COMPARISON OF THE LOUDNESS OF PURE TONES.—B. Kingsbury. (*Physical Review*, 29, February, 1927, p. 373.)

Abstract of a Paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

Tests showed that if the amplitudes of pure tones are increased in equal ratios, the loudness of low frequency tones increases much more rapidly than that of high frequency tones for frequencies up to 700 cycles when the rate becomes nearly uniform. The variability of the data was separated into a factor expressing dissimilarity of ears and another expressing errors of observers' judgment: dissimilarity of ears was found to cause more variation than errors of observers' judgment.

SUR LES PROPRIÉTÉS DIÉLECTRIQUES DES GAZ IONISÉS (On the dielectric properties of ionised gases).—H. Gutton and J. Clément. (*Comptes Rendus*, 184, 21st February, 1927, pp. 441-443.)

Owing to the interest of this question for the investigation of the propagation of electro-magnetic waves in the upper atmosphere, the authors undertook to make measurements employing continuous oscillations, separating the effects of ionisation on the period and the damping of a resonator.

The resonator of wavelength 408.5 cm. consisted of two sheets of copper (20.2 × 4 cm.), 4 cm. apart, joined by a copper wire 92 cm. long, in the middle of which a thermo-electric junction was inserted, joined to a galvanometer. A valve oscillator whose wavelength could be varied was placed near the resonator. By observing the deviations on the galvanometer for different wavelengths, the resonance curve of the resonator could be traced and its period of oscillation found. A glass tube, through which a discharge could be passed to ionise the gas it contained, was placed parallel to the longer sides of the plates of the condenser. For different pressures and ionisations, the wavelength was measured on which the resonator was tuned and the current of resonance.

At the lowest pressures, weak ionisation decreases the wavelength of the resonator and this diminution indicates an apparent decrease of the dielectric constant below unity. Eccles' theory (*Proc. Roy. Soc.* 87, 1912, p. 79) explains this diminution simply by the inertia of the electrified particles to determine the motion of these particles in the oscillating electric field. By increasing the ionisation, the wavelength changes fairly suddenly to a value greater than that corresponding to the strongly ionised gas, thus indicating an increase of the dielectric constant. The change takes place by ionisations causing very marked damping in the resonator. This can only be explained by bringing in quasi-elastic forces, which could result from the mutual actions of the ions and the movements they call forth. When the ionisation is reached for which they compensate the forces of inertia, the sign of the difference of phase between the electric force and the elongation of the oscillations of the electrified particles becomes reversed, which changes the direction of variation of the dielectric constant. The amplitude of the oscillations then becomes very great and calls forth the strong damping of the resonator observed. Lastly, at the highest pressures, forces analogous to friction have the preponderating influence, and curves of the same shape are found as those obtained for an electrolytic solution of increasing concentration.

THEORY OF THE MAGNETIC NATURE OF GRAVITY.—C. Sagui. (*Physical Review*, 29, February, 1927, p. 371.)

Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, December, 1926.

The only physical reality considered necessary is the electromagnetic field. A ray of light is thought of as formed of a series of extremely small electrical resonators without ohmic resistance. In such a resonator a sine disturbance once started will go on without end. A transmitting medium for the energy is not considered necessary. The electromagnetic waves would consist of a sort of magnetic quanta moving to and fro. Matter would be built up similarly of electrical resonators, so that the gravitational force would be represented by the integral value of all the magnetic quanta of the elementary resonators moving to and fro about the body in a radial direction, at a distance which should be a function of the total number of resonators composing the body in question. Thus the gravitational field would not be infinite, but limited by the mass of the body itself. A ray of light going through a gravitational field of such a kind must modify its frequency within certain limits. A second modification of its frequency would result from the motion of the earth, in such a way that when the motion was in the same direction as that of the ray the frequency would become smaller.

WHAT IS ELECTRICITY ?— (*Electrician*, 25th March, 1927, p. 316.)

Abstract of the Faraday Lecture delivered by Prof. W. M. Thornton at the Institution of Electrical Engineers on 17th March, 1927.

MAGNETIC INDUCTION IN CONTINUOUS MEDIA.—C. Burch and N. Ryland Davis. (*Nature*, 119, 5th March, 1927, p. 353.)

THE QUANTUM THEORY OF THE EMISSION AND ABSORPTION OF RADIATION. — P. Dirac. (*Proc. Royal Society*, 114A, March, 1927, pp. 243-265.)

STATIONS: DESIGN AND OPERATION.

UNITED STATES. (*Electrical Review*, 18th March, 1927, p. 436.)

Station WRNY, in New York City, is preparing to transmit with a buried aerial. The aerial will be drawn through a terra-cotta pipe buried about 6 ft. underground at Coytesville, N.J., where the transmitter is located. During the war extreme ranges were obtained by underground transmission, and WRNY will be the first station in America to broadcast on such an underground aerial.

A report issued at Washington, D.C., by the United States Department of Commerce, says that there are 164 broadcasting stations in Europe, over 700 in the United States, 85 in the remainder of North America, 38 in South America, 16 in Asia, 28 in Oceania, and 9 in Africa.

RADIO CONTROL FOR AMERICA.—(*Electrician*, 98, 11th March, 1927, p. 275.)

The Radio Control Act just signed by President Coolidge empowers a Commission of five to establish broadcasting in the United States on the same lines as now prevailing in Europe. At present there are 733 broadcasting stations operating on a wave-band which can accommodate only 89.

BROADCASTING IN SOUTH AFRICA.—(*Electrician*, 18th March, 1927, p. 308.)

Arrangements have been made between the Minister of Posts and Telegraphs of South Africa and the African Theatres, Ltd., whereby broadcasting in Johannesburg will be resumed. A company to be called the African Broadcasting Co., Ltd., will take over the Johannesburg station this month, when shares will be offered to the public. The Government will have two seats on the directorate, and a third seat will be allocated to the Transvaal Radio Society.

GERMAN COMPETITION ABROAD.—(*Electrician*, 25th March, 1927, p. 340.)

The German Telefunken firm has been successful in obtaining the contract for the new wireless station at Bangkok. There have been three stations in that country for a number of years, but none is capable of transmitting messages effectively to Europe. It has now been decided to build a station for short wave, duplex, and high-speed working between Siam and Europe, and tenders were obtained from the leading British, French, and German companies.

ITALY: BROADCASTING CONTROL.—(*Electrical Review*, 25th February, 1927, p. 303.)

The Department of Overseas Trade learns from a reliable source that a Commission for the control of broadcasting services has been set up in Rome by Royal Decree. In addition to control, the Commission is charged with examining and reporting on the most suitable methods of developing and improving broadcasting from technical, artistic, and educative points of view.

PERU: NEW REGULATIONS.—(*Electrical Review*, 4th March, 1927, p. 349.)

The Government having taken over all broadcasting in Peru, station OAX has become State property and new regulations have been issued by the Administration of Posts, Telegraphs and Wireless applying to all receiving sets. It is pointed out that a licence does not authorise the use of a set for commercial purposes, that single-wire antenna must not be over 100 ft. long nor double wire over 140 ft., and that the owner of a set may make no use whatever of any information so received.

POLAND: NEW STATION.—(*Electrical Review*, 18th February, 1927, p. 261.)

The newest European long-wave station is that at Warsaw, built by the Marconi Co., for the Polish Broadcasting Co. Power is obtained from the city supply at 3,000 volts, three-phase, being transformed at the station to 210 volts. The transmitter, which is designed on the same lines as that at Daventry, works on 1,013 metres with an input of 10kW to the main oscillator valve. The aerial is carried on two self-supporting lattice steel masts 75 metres high.

TURKEY: FIRST STATION.—(*Electrical Review*, 18th March, 1927, p. 436.)

Turkey has installed the first broadcasting station of the Near East. The studio is in the G.P.O. Stamboul and is linked to the transmitter in Osmanic by nine miles of cable. The station was constructed by the Compagnie Générale de Télégraphie sans Fil, Paris, with a power of 6kW, and began operations last month.

SHORT-WAVE BEAM TRANSMISSION.—(*Electrician*, 25th March, 1927, pp. 319-320.)

Description of the equipment of the transmitting station near Grimsby, and the receiving station near Skegness, erected for the British Post Office, by the Marconi Company, for communication with India and Australia.

MISCELLANEOUS.

SUR LA TÉLÉVISION. PREMIERS RÉSULTATS DANS LA TRANSMISSION DES IMAGES ANIMÉES (On television; first results in the transmission of moving pictures).—Belin and Holweck.—(*Comptes Rendus*, 184, 28th February, 1927, pp. 518-520.)

The authors describe their method of effecting television, in which the cathode-ray oscillograph is employed for receiving, and the first results obtained.

TELEVISION.—(*E.W. & W.E.*, April, 1927, pp. 239-240.)

Contribution to the discussion of Mr. Baird's paper before the Radio Society, by Mr. Dénes von Mihály, of Hungary.

PHOTOTELEGRAPHY.—T. Thorne-Baker. (*E.W. & W.E.*, April, 1927, pp. 229-238.)

A TOUR ROUND SAVOY HILL.—(*Wireless World*, 9th, 16th and 30th March, 1927.)

Parts V, VI and VII, dealing respectively with the Control Room, arrangements for Simultaneous Broadcasting, and Studio Organisation and rehearsal of Programmes.

GLYPTAL.—H. Warren. (*Electrician*, 18th March, 1927, pp. 286-287.)

Description of a new synthetic resin which is a distinct improvement on the phenol-formaldehyde resins in respect of resistance to arcing and discharge flexibility, and ability to bond mica.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

PROPAGADO DE ONDOJ.

MALLONGONDA SENFADENA TELEGRAFIO.

Resumo de prelego legita de S-ro. T. L. Eckersley ĉe la Senfadena Sekcio de la Institucio de Elektraj Inĝenieroj, Londono, je 2a Marto, 1927a.

La prelego donas ĝisdatan revuon pri mallongonda praktikado. En la unua parto oni diskutas antenajn sendajn karakterizojn, speciale la kalkuladon de vertikalaj polusaj diagramoj, kiuj montras la okazojn por vertikalaj kaj horizontalaj paroj. En la dua parto, direkto-trovaj eksperimentoj je mallongaj ondoj estas priskribitaj. Eksperimentoj per "formato-de-cifero-ok" kaj kardioidaj diagramoj pri apudaj kaj malapudaj stacioj estas diskutitaj. Oni konkludas, ke la foresto de minimumoj ĉe la kadro ("cifero-de-ok") estis kaŭzita ĉefe pro horizontala polusita radio, kiel ĉe longaj ondoj, kaj ke la plimulto de la radioj sekvis la grandan cirklan vojon kaj frapis la ricevilon preskaŭ paralele je la tero. En la tria sekcio, sendaj provoj estas pritraktitaj je ondlongoj de 25 ĝis 10 metroj, kaj rezultaj kurvoj je sendadoj (al Aŭstralio, Kanado, k.t.p.) estas montritaj. Grava konkludo estas, ke la trafpovo de taglumaj signaloj varias proksimume proporcie laŭ la kvadrato de la frekvenco.

La kvara parto de la prelego estas dediĉita tute al teoria diskutado, kiam la aŭtoro disvolvas teorion de maldensiĝo, kaŭze de absorbo ĉe la supra tavolo, kaj diskutas la diferencon inter sendadaj kondiĉoj por longaj kaj mallongaj ondoj tage kaj nokte.

Mallonga raporto pri la diskutado, kiu sekvis la legadon de la prelego, estas ankaŭ presita.

PROPRECOJ DE CIRKVITOJ.

LA REZULTANTA KAPACITO DE ANTENAJ SISTEMOJ UZANTAJ SERIAGORDAJN KONDENSATOROJN. —W. H. F. Griffiths.

La aŭtoro unue aludas al antaŭa artikolo (en Decembra numero) pri la leĝoj de rezultanta kapacito de du kondensatoroj serie konektitaj. Oni montras ke, rilate al anteno kaj seria kondensatoro, la kutima leĝo pri du kondensatoroj seriaj ne povas esti ĉiam aplikita.

La aŭtoro poste traktas pri diversaj ekzemploj de aldona induktanco kaj seria kondensatoro, ilustranta la kalkulojn per kurvoj de indukta, kapacita kaj tuta reaktanco ĉe la diversaj ekzemploj.

Oni konkludas ke, se seria antenagorda kondensatoro estas desegnita (traktanta la antenan kapaciton nur kiel fiksvaloran kondensatoron serian), ĝia desegna leĝo estos, ĝenerale, proksimume korekta por ĉiuj valoroj de aldona induktanco pligrandaj ol duoble je la induktanco de la anteno, kaj treege proksimume korekta kiam uzita kune kun bobenoj dekoble pligrandaj ol la antena induktanco.

RICEVADO.

NOVA EVOLUIĜO JE REZISTANCA AMPLIFADO.—F. M. Colebrook.

La artikolo diskutas la sistemon (ŝulditan al von Ardenne kaj Heinert) de la uzado de anodaj rezistancoj megomgrandaj anstataŭ ol la kutimaj 50,000 ĝis 100,000-omaj, kiam oni uzas rezistanc-kapacitan kuplon por malaltfrekvenca amplifado. La ĝenerala teorio de valvo kun rezistanco en la anoda cirkvito estas diskutita, kaj oni montras, kiel la valoroj de interna kaj ekstera rezisteco en la nova praktiko produktas bezonitan longecon de rekta karakterizo. Oni ankaŭ montras, ke la ordinara esprimo $\frac{R}{R_a \times R}\mu$, kunkonsiderante la modifitan valoron de R_a sub la novaj kondiĉoj. Funkciaj karakterizoj de diversaj valvoj estas montritaj, notinda punkto estante la ebleco de konsiderinda malgrandiĝo de normala filamenta kurento, kaj konservado de ambaŭ alt-tensia kaj malalt-tensia fontoj.

La aŭtoro tiam pritraktas la aplikon al multŝtupaj amplifikatoroj. La efektoj de elektrodaj kapacitoj estas diskutitaj, kaj ekvivalenta cirkvito por kupla ŝtupo montrita, per kio la valoro de la kupla kondensatoro estas kalkulita.

Oni konkludas, ke 80 ĝis 95 procento de la volt-kvanta faktoro de la valvo estas obtenebla, kaj ke malaltfrekvenca amplifado per ĉi-tiu metodo estas preskaŭ tute libera de amplituda aŭ frekvenca distordado se la konstrueroj estas de taŭgaj dimensioj. Sugestitaj valoroj estas :—

Anodaj Rezistancoj—1 ĝis 2 megomoj por normalaj valvoj, 2 ĝis 3 megomoj por alt-μ valvoj.
Kradaj Rezistancoj—3 ĝis 5 megomoj.
Kuplaj Kondensatoroj—1,000 ĝis 2,000$\mu\mu$F.

DIVERSAJOJ.

RESUMOJ KAJ ALUDOJ.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

MATEMATIKO POR SENFADENAJ AMATOROJ.—F. M. Colebrook.

Daŭrigita el antaŭaj numeroj. La nuna parto traktas pri la Binoma Teoremo kaj Eksponenciala Serio, kaj finas Parton I de la originala tem-dividigo de la aŭtoro.

FOTO-TELEGRAFIO.—Raporto pri lekcio kaj demonstracio ĉe la Radio-Societo de Granda Britujo de S-ro. T. Thorne Baker, M.I.R.E., F.Inst.P., F.R.P.S., je 23a Februaro, 1927a.

La lekcianto unue diskutas fruajn eksperimentojn kaj rezultojn je fototelegrafio, kaj la uzadon de seleniaj kaj fotoelektraj ĉeloj. La duontona klišo (uzita por ordinara presado) estas poste diskutita, kaj frua metodo sendi per kodo estas priskribita. Poste, fruaj eksperimentoj de Korn kun seleniaj ĉeloj, sekvita de la Belin'a sistemo de reliefa presado de la bildo sendota, kiu estas cilindrigita kaj skribita per stiluso.

Post diskutado pri la Amerikaj sistemoj de Ives kaj de Ranger, la lekcianto priskribis kaj demonstraciis aparaton de sia propra evoluigo. Dum la demonstracio, bildo estis sendita per radio trans la lekcia teatro.

La artikolo estas bone ilustrita per ekzemploj de bildoj sendita per la diversaj metodoj, inkluzive tiun senditan ĉe la demonstracio, kaj per diagramoj klarigantaj la sistemojn priskribitajn.

TELEVIDADO.

Kontribuaĵo de S-ro. Dénes von Mihály, de Hungarujo, al la diskutado pri la prelego pri ĉi tiu temo de S-ro. J. L. Baird, ĉe la Radio-Societo de Granda Britujo (publikigita en *E.W. & W.E.*, Decembro 1926a). La skribinto kritikas diversajn el la diroj de S-ro. Baird, inkluzive la agadon de vida purpuro, fendetojn en la turniĝanta disko, rapideco de disko, k.t.p.

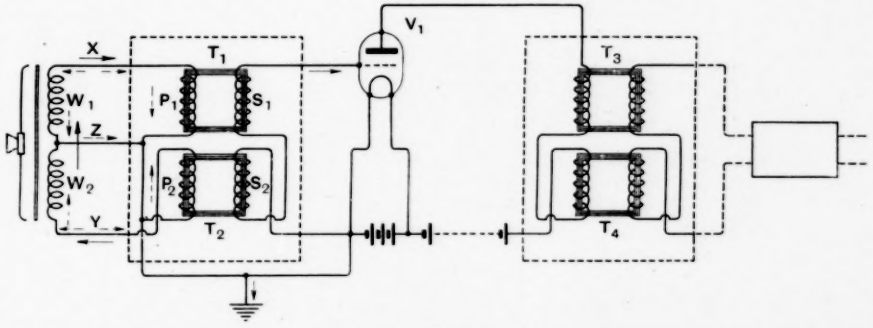
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each

MICROPHONE AMPLIFIER CIRCUITS.

(Application date, 9th November, 1925. No. 266,029.)

E. A. Graham and L. H. Paddle describe in the above British Patent some microphone amplifier circuits in which means are provided for eliminating induction effects and so-called reaction effects between stray fields between the output and input circuits. The invention relates to a centre point earth system in which two closed core transformers mounted side by side are used in the input and output circuits of the valve. The arrangement of the particular circuit is shown in the accompanying illustration. The microphone is of the magnetophone type comprising a centre tapped output, such, for example, as two windings W_1 and W_2.



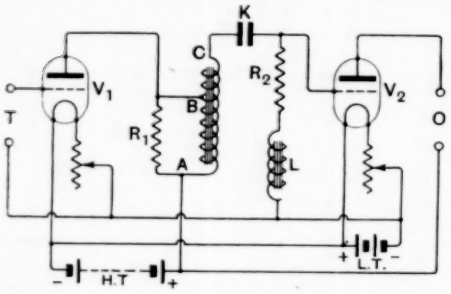
The input of the amplifier consists of two transformers T_1 and T_2. The specification states that these are placed side by side so that the fields are in the same sense. The secondaries S_1 and S_2 of the two transformers are connected in series, and are connected between the grid and filament of the valve V_1. The primaries of the transformers P_1 and P_2 are also connected in series and the two outers are connected by leads X and Y to the microphone terminals, while the centre point of the primaries is connected to the centre point of the magnetophone by a lead Z which is earthed. The output circuit of the valve contains transformers T_3 and T_4 connected in series, no centre point being employed. It will be obvious that should the leads X, Y, Z lie in any stray field any

currents induced in the system will balance out so far as the secondary potentials of the transformers T_1 and T_2 are concerned. In other words, the effect of any induced current will not be amplified by the valve V_1. Microphone potentials, however, will not balance out, and will produce potentials across the secondary of the input transformer, which will be subsequently amplified by the valve. The specification also states that it is necessary when using long microphone leads to use earthed sheathed wires, the sheath being connected to the centre point.

AN AUTO-COUPLED TRANSFORMER.

(*Application date, 23rd October, 1925. No. 264,910.*)

A special type of auto-coupled intervalve transformer is described in the above British Patent Specification by E. A. Graham and L. H. Paddle. The particular circuit arrangement which is claimed in the invention is shown in the accompanying diagram. The amplifying valve V_1 is provided

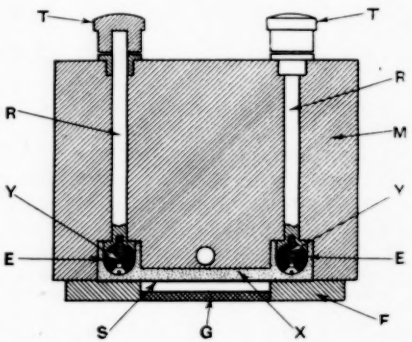


with input terminals T, while the anode circuit contains the primary winding AB of an auto-coupled transformer. The primary winding AB is further shunted by a resistance R_1. Since the transformer is auto-coupled a stopping condenser must, of course, be included between the high potential end of the secondary winding, *i.e.*, C, and the grid of the next valve. Accordingly, a condenser K is inserted as shown, and this necessitates the use of a grid-leak R_2, which is connected in series with a low frequency choke L. The output of the second valve V_2 is shown at O, which can include the primary winding of another similar transformer arrangement. The specification is fairly detailed, and includes several modifications. In another arrangement the transformer is provided with tappings, so that various ratios and degrees of voltage amplification can be obtained. In yet another modification the full winding is shunted by a resistance or potentiometer, the sliding arm of which is connected to the coupling condenser, and, therefore, controls the voltage which is applied to the grid of the next valve.

ANOTHER REISZ MICROPHONE.

(*Application date, 11th August, 1926. No. 258,542.*)

E. Reisz describes in the above British Patent a modification of the type of microphone which he has previously developed. It is mentioned in the specification that the response of the previous type of microphone is affected very materially by the size of the granules. If the granules are comparatively large there is appreciable space between them, which allows the sound waves at the higher frequencies to be absorbed, thereby doing no work on the granules as a whole, and lowering the sensitivity of the microphone at the higher frequencies. Also the thickness of the layer of the carbon has a marked effect upon the frequency characteristic. The present invention overcomes these difficulties by using a mixture of granules of various sizes, very fine dust being mixed with two sizes of granules so that the air spaces between the dust and the granules are filled up. It is stated that a satisfactory mixture consists of 47 per cent. of grains of 0.07 mm. diameter, and 22 per cent. of dust not exceeding 0.0015 mm. diameter, the remainder consisting of grains of intermediate sizes. The accompanying diagram shows a cross section of a microphone incorporating a carbon layer of this type. The microphone consists of a block M of marble or other



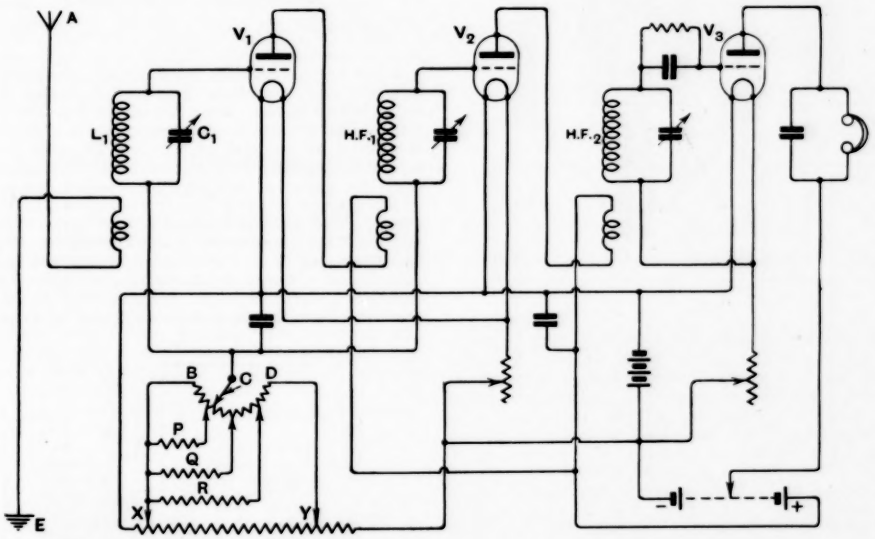
solid material, a portion of the front of which is removed at X and filled with the carbon mixture previously described. Two further recessed portions shown at Y contain electrodes E of carbon or non-oxidisable metal connected by rods R to terminals T located at the back of the microphone. The granules are held in position by means of a thin sheet of rubber S so stretched that the natural period is below 50 cycles per second. The front of the rubber is then covered with gauze G fixed to a frame F so proportioned that the frame lies directly in front of the carbon or other electrodes E. This is necessary so that the sound waves are prevented from falling directly on the electrodes, which might tend to vibrate and render the microphone resonant at their frequency.

CONTROLLING REGENERATION.

(*Convention date (U.S.A.), 4th June, 1925. No. 253,072.*)

A method of controlling regeneration is described in the above British Patent by the Lovejoy Corporation and D. R. Lovejoy. The method refers

to controlling the regeneration by damping the input circuits of a series of cascaded valves by applying a positive potential to the grid. The specification points out that the positive potential which is sufficient just to prevent the maintenance of continuous oscillations varies with the ratio of the inductance and capacity in the tuned circuit, and is, therefore, not constant for all settings of the tuning condenser. According to the invention, however, the tuning control and the potentiometer control are mechanically linked. The accompanying diagram should make the scheme quite clear. Here the aerial circuit AE is coupled to the input circuit L_1 C_1 of the first valve V_1. The output of this valve is coupled to the next amplifying valve V_2 by means of a high frequency transformer HF_1, containing a tuned secondary, a second high frequency transformer HF_2 being used between the second amplifier and the detector valve V_3. The lower end of the tuned input circuit of the valve V_1 and the lower end of the secondary winding of the transformer HF_1 are not connected directly to the filament, but to the slider arm C of a potentiometer BCD. The ends BD of the potentiometer BCD are not connected directly across the filament leads of the valve, but across two variable tappings X and Y on a resistance connected across the filament supply so that the actual potential drop across the potentiometer BCD can be finely regulated. The specification points out that by mechanically linking a condenser shaft with the potentiometer arm the relationship between the change of capacity and potential difference between the arm and one end of the potentiometer may not fulfil the required law which is necessary for stabilisation. In order to bring this about it will be necessary to wind the potentiometer with resistance wire of varying specific resistance, or adopt similar means, so that for a given angular displacement the change in resistance would not be a linear function. According to the invention, however, this law is fulfilled by connecting in parallel with the potentiometer BCD auxiliary resistances P, Q, and R arranged as shown. This is in effect equivalent to winding the potentiometer in sections each having different ohmic resistances. The remaining portion of the circuit is quite normal, and is, therefore, not described in detail. Another modification of the invention utilises a similar principle, in which a filament rheostat can be linked with another control so as to bring about a reduction of amplification by dimming the filament.

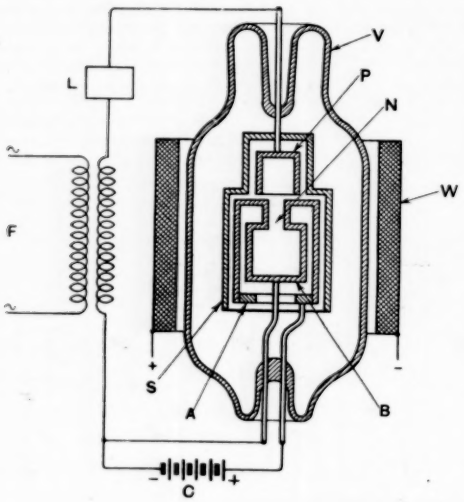


AN INTERESTING DISCHARGE TUBE.

(*Convention date (U.S.A.), 5th March, 1925. No. 248,721.*)

A very interesting form of discharge tube is described by the Raytheon Manufacturing Company and C. G. Smith in the above British Patent, which is very detailed and contains considerable information regarding the functioning of discharge tubes, particularly those containing an appreciable proportion of vapour. One form of tube is illustrated diagrammatically in the accompanying illustration. The glass envelope V is of cylindrical form and is situated within a winding W so that a longitudinal magnetic field can be applied to the electrode system contained within the bulb. The particular valve is a two electrode arrangement for rectifying purposes, and is provided with a cathode and an anode. The cathode consists of two concentric

cylinders A and B joined at their upper ends by a neck N. The anode P also consists of a cylinder closed at its upper end, the open end being situated above the neck N. A heat shield S is arranged in the manner indicated and is supported by the anode lead. The object of this is to confine the

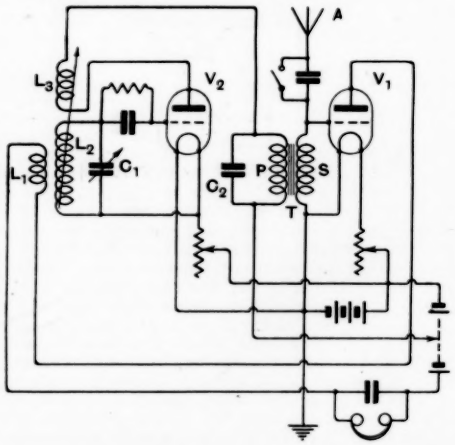


heat from the cathode, and the shield may be made of highly polished metal. The rectifier is shown connected to a source of supply from a transformer F, and is working into a load L. A battery C heats the cathode comprising the two cylinders. The valve is completely evacuated with the exception of a small amount of cæsium, or another alkali metal. This may be in the solid or vaporous form, but preferably a certain proportion should be in the solid form. The neck N is so constructed that the diameter is preferably less than the mean free path of the vapourised molecules outside the cathode, which, incidentally, is preferably made of tungsten. The connection of the battery C to the cathode should be such that the positive pole is connected to the outer cylinder. When the interior of the cathode is heated the vapour, particularly in the region of the neck, is ionised, and owing to potential drop down the neck the vapour is pumped into the cathode until a relatively high pressure is obtained therein. Under these conditions, that is the cathode being full of ionised alkali vapour under considerable pressure, an electronic discharge from the cathode through the neck to the interior of the anode is easily obtained at a comparatively low anode potential with respect to the cathode. There can be no reverse current because the interior of the anode does not contain highly ionised vapour under pressure. The space charge near the interior surface of the cylindrical anode is balanced out by the positive ions which are generated owing to the high temperature of the adjacent cathode, the two electrodes, of course, being enclosed together within the common shield S. A particular feature of this type of discharge tube lies in the fact that the rectifying property is not appreciably affected by the load to which it is connected, and accordingly a heavy load does not tend to prevent the device from rectifying properly. The object of the magnetic field produced by the windings W is to direct the electronic discharge from the cathode through the neck, and also to prevent it locating itself actually in or around the neck. Several other modifications are described in the specification, and also include tubes containing a control electrode, and those particularly interested in this type of discharge tube are referred to the specification for greater detail.

MINIMISING RADIATION.

(Convention date (U.S.A.), 18th April, 1925. No. 250,969.)

A receiving circuit particularly designed to minimise radiation from the aerial is described by S. Y. White in the above British Patent Specification. The invention really consists in connecting the aerial to the grid of a valve, the grid circuit of which contains no high-frequency reactance, so that the value of any radio-frequency potentials existing across the grid circuit will be comparatively small. This necessarily means that the particular valve will not function efficiently at radio frequencies but the valve is used as a low frequency amplifier and also as a means of transferring energy from the aerial to a detector valve. One method of accomplishing this is shown in the accompanying diagram.



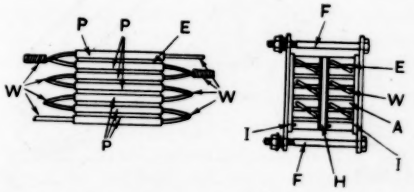
An aerial A is connected to the grid of a valve V_1, the grid circuit of which contains the secondary winding S of an intervalve transformer T. The anode circuit of the valve contains an inductance L_1 coupled to a tuned circuit L_2 C_1 connected to a detector valve V_2. The circuit L_2 C_1 is tuned

to the desired frequency of reception, while the anode circuit of the valve contains a reaction coil L_3. The anode circuit of the valve V_2 also contains the primary winding P of the intervalve transformer T, this winding being shunted by a capacity C_3 to by-pass any high frequency component. Radio-frequency potentials occurring across the aerial and earth will be transferred through the valve V_1 partly by capacity effect, and partly by a certain amount of amplification to the valve V_2, through the medium of the high frequency inductance L_1 in the anode circuit of the first valve. The oscillations induced into the tuned circuit $L_2 C_1$ will be rectified by the valve V_2. The rectified currents will be transferred by the intervalve transformer T to the grid circuit of the valve V_1, which will amplify them, the final currents being detected by the telephones, which are also included in the anode circuit of the valve V_1. The remainder of the circuit is quite straightforward, and will, therefore, not be described in detail. The specification also mentions several alternative arrangements and similar applications of the principles involved.

A THERMO-ELECTRIC GENERATOR.

(*Application date, 22nd March, 1926. No. 265,519.*)

A thermo-electric device is described by H. A. Roberts in the above British Patent Specification, the accompanying diagram illustrating the mode of construction. The elements of the device consist of alternate plates of positive and negative thermo-electric active metals P. The plates have cast into them wires W, the ends of which are twisted together so as to join the elements either in series or parallel, according to the relative voltages and currents which are required. The plates are separated from each other by washers E of asbestos

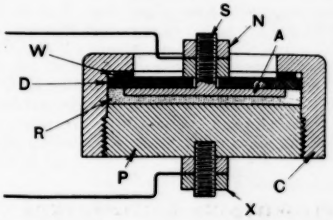


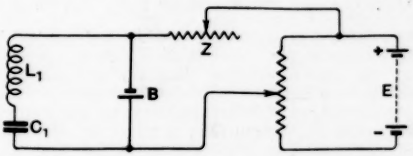
paper or similar heat-resisting insulating material. The assembly of plates is then clamped together in a framework F, which needs no description, the edges of the plates being insulated by strips I. The portion H represents a heater which may be an electric element, or it may be replaced by a series of gas flames.

AN INTERESTING DEVICE.

(*Application date, 9th October, 1925. No. 265,652.*)

L. Levy describes in the above British Patent an exceedingly interesting device which can be used as a rectifier or a generator or modulator of oscillations. The rectifier is of the aluminium and sulphide contact variety. The specification mentions that rectifiers consisting of aluminium in combination with cuprous sulphide have been used, but do not generally function satisfactorily after some time. This is supposed to be due to the fact that the cuprous sulphide becomes attached to the aluminium, and one then has cuprous sulphide in contact with cuprous sulphide, which does not rectify. This disadvantage is overcome by a method of construction disclosed in the

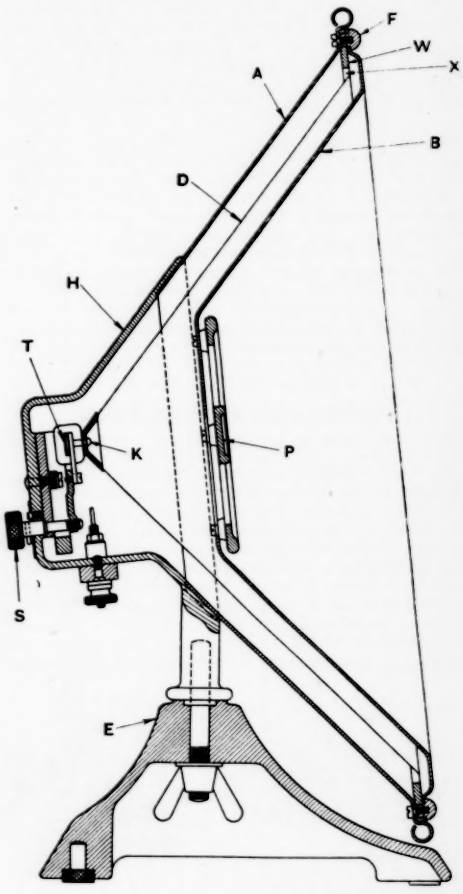




specification. The rectifier shown in the accompanying diagram comprises a copper or aluminium cup C provided with a screwed copper plug P. Inside the cup there is an insulating disc D of bakelite. Attached to the insulating disc D is an aluminium disc A located by means of a stud S and nuts N. The plug P is also provided with another stud and nuts shown at X. The space R is filled with the rectifying compound which is made in the following manner: Copper sulphide is first obtained by heating finely divided copper with sulphur, the two being arranged more or less in molecular proportion, but with a slight excess of sulphur. The resulting sulphide is then ground in a mortar until the powdered grains have diameters of the order of 0.2 of a millimeter. The powder is then sieved so as to remove any trace of metallic particles. The granular powder is then made into a paste by mixing it with a sulphuretting liquid such as ammonium hydro-sulphide. It is essential that the aluminium disc A, shown in the diagram, be chemically clean, and, particularly, free from oxide, and to ensure this the face and edge in contact with the sulphide paste is very carefully polished, this operation being carried out immediately before assembly in order to prevent the formation of oxide. Another essential feature of the device is that it must be gas tight. In order that gaseous pressure caused by the vapourisation of the liquid used for forming the paste may be produced inside the apparatus an annular washer W is included. It is stated that the increase of temperature caused by the current through the rectifier vapourises a

portion of the liquid, and this produces the necessary sulphuretting atmosphere. The specification describes various known arrangements of the rectifier for delivering high and low tension current to wireless receivers. One point of interest in connection with high voltage supply lies in the fact that it is preferable not to use a series of rectifying cells across the full voltage, but to supply each cell or small number of cells from a separate transformer winding. Another peculiarity of the device lies in the fact that it exhibits a negative resistance characteristic, thereby enabling it to be used as an oscillation generator. A suitable circuit is also shown in the diagram where a rectifier B in shunt with the tuned circuit L_1 C_1 is supplied through an impedance Z from a source of potential E. The arrangement, of course, is similar to the well-known Arc or Duddell circuit. Another modification of the invention lies in its use as a simple detector for wireless signals, when the sulphide arrangement is used in conjunction with a fine aluminium wire.

AN ENCLOSED CONE LOUD-SPEAKER.

(*Application date, 28th November, 1925. No. 266,271.*)

An enclosed type of loud-speaker is described by S. G. Brown in the above British Patent Specification, the accompanying diagram illustrating a suitable form of construction. The main features of the invention will be described in some detail. The conical diaphragm D is of paper or other light rigid material, and is connected at the base A to a reed type of drive or telephone movement T provided with an adjusting screw S. This type of movement has been previously described, and is no doubt familiar to readers. The diaphragm is enclosed between two metal cones. The back cone A is fixed to the housing H, which contains the telephone mechanism, which in turn is fixed to a supporting stand E. The cone A is actually provided with perforations, although this is not shown. The back cone A is attached at its periphery to the front cone B, the two being held together by bolts passed through their flanged edges at F. This junction also holds in position a ring W of wood or similar material. The periphery of the sound-emitting diaphragm D is attached to this ring W by means of very thin tissue paper or similar material at X. Referring again to the front cone, this is truncated and provided with a perforated circular disc P, through which the sound from the diaphragm can pass. The chief object of the invention is to secure a light and free method of supporting the diaphragm, and, at the same time, protect it from mechanical injury.